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H.M. Oscar II., King of Sweden and Norway, K.G.

Honorary Member of the Iron and Steel Institute

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H.M. OSCAR II., KING OF SWEDEN AND NORWAY, K.G.

HONORARY MEMBER OF THE IRON AND STEEL INSTITUTE

THE JOURNAL

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[illegible]ON AND STEEL INS[illegible]

VOL. [illegible]

[illegible]

LONDON
[illegible]

H.M. Oscar II, King of Sweden and Norway, K.G.
Honorary Member of the Iron and Steel Institute

No. II 1898

THE JOURNAL

OF THE

IRON AND STEEL INSTITUTE

VOL. LIV.

54

EDITED BY

BENNETT H. BROUGH

SECRETARY

LONDON
E. & F. N. SPON, LIMITED, 125, STRAND
NEW YORK: SPON & CHAMBERLAIN, 12, CORTLANDT STREET
SOLD ALSO AT THE OFFICES OF THE INSTITUTE
28, VICTORIA STREET, LONDON, S.W.
1899

Printed by Ballantyne, Hanson & Co.
At the Ballantyne Press

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Vol. liii., p. 137, lines 1 and 2 should be transposed to the top of p. 136.

THE IRON AND STEEL INSTITUTE.

SECTION I.

MINUTES OF PROCEEDINGS.

STOCKHOLM MEETING.

The AUTUMN MEETING of the IRON AND STEEL INSTITUTE was held at the Palace of the Nobility (Riddarhuset) on Friday, August 26, 1898—Mr. EDWARD P. MARTIN, President, in the chair.

Baron TAMM, the Governor-General of Stockholm, in welcoming the Institute to Sweden, said: Gentlemen, on behalf of the Swedish ironmasters, who have made bold to invite the renowned Iron and Steel Institute to visit our country, and also on behalf of the inhabitants of this city of Stockholm, I beg to bid you a most hearty welcome to us, to Sweden, to its capital, and to this building, where formerly the political interests of our country were deliberated and discussed.

We cannot but consider it as a most distinguished honour you are conferring on us by assembling here for this annual meeting, and we beg to return our best thanks to the President and Council, who have conceived the idea of selecting our country for this purpose, and to all the members of the Institute for carrying out this generous idea by accepting our humble and respectful invitation. As coming events throw their shadows before, your arrival has been preceded by the prestige and high reputation of the Iron and Steel Institute.

We have learnt long ago to admire the genius of your inventors, the grandeur and universal bearing of your discoveries, your pre-eminent practical energy, and your grand style of managing to create and to develop the iron industry of your country. This industry has been practised even in Sweden ages ago, although we have only succeeded as yet in obtaining but rather modest results on a quantitatively modest scale, and thus it is —and how could it be otherwise?—that we Swedish ironmasters greet your coming and the sight of you in our midst with joy and delight, hailing you as our teachers, our masters.

I beg to appeal to your benevolent complacency and forbearance, that you will kindly accept the plain and unpretending reception, which is all we have to offer in answer to your generous coming.

We should be very happy if we succeeded, to some extent, in rendering your stay amongst us at least so far tolerable that your time may not be altogether wasted, and that the pains and trouble you have taken by leaving your comfortable homes may not prevent you from leaving with a kind remembrance of our country, our city, and our free institutions.

And now I have the honour to offer this hall to the members of the Iron and Steel Institute for their meeting, and beg to request that it may please the honourable President of the Institute to take this chair, and to open the meeting.

The PRESIDENT said the Council and members of the Institute highly appreciated the compliment conveyed by Baron Tamm receiving them in his official capacity as Governor-General of Stockholm. But it was especially gratifying to the members of the Institute to be received by his Lordship, not only as Governor-General of Stockholm, but also as President of the ancient body — the prototype of their own Institute — the Jernkontor, an association that dated back to a time when the oldest English works were in their infancy, and still conferred with unabated energy the benefits which had done so much for Sweden and for its iron and steel manufactures.

Many of them were visiting Sweden and the beautiful city of Stockholm for the first time, and they could not forget that in visiting this country they were on classic ground—the nursery of

the iron and steel industries, the birthplace of Rinman, Bergman, Scheele, and Berzelius. He again thanked Baron Tamm and the Reception Committee most heartily on behalf of the Institute, and he could only add that he failed to find words to thank their hosts sufficiently for their kind and hearty welcome.

He had an announcement to make, which he was sure the Institute would receive with acclamation, and that was that, in recognition of Baron Tamm's merits as ironmaster and statesman and President of the Jernkontor, the members of the Council had unanimously elected him an Honorary Member of the Iron and Steel Institute. This was the highest honour that they could bestow upon his Lordship.

Baron TAMM, in reply, begged to return his most hearty and sincere thanks for the high honour they had conferred upon him, and he ventured to accept it in the name of the Jernkontor.

An address of welcome was also given by Mr. A. NORDSTRÖM on behalf of the Society of Swedish Engineers and Architects. He said friendly relations had for a long time existed between Great Britain and Sweden, and they had the most pleasant technical and commercial connections with the people of the United Kingdom, connections which they hoped that meeting would strengthen and enlarge. When they received the notice that the Institute were going to hold their meeting in Stockholm, they felt it a pleasant duty to try to make their stay as interesting as possible. In order that they might get a good idea of their local industry, they had arranged for admittance to some of their more interesting factories and technical establishments. Of course these works were not to be compared as to dimensions with similar works in Great Britain, but still they thought there might be something of interest even for visitors from that country.

The PRESIDENT thanked the Society of Swedish Engineers and Architects for having so kindly arranged visits to the different works in Stockholm, which he was sure would be fully appreciated and taken advantage of by all the members of the Institute.

The SECRETARY read the Minutes of the last Meeting, which were confirmed, and signed by the President.

The PRESIDENT said he had now to announce that the Council had selected their next President. It had usually been the case that in their choice they alternated between practical and scientific men, and he thought that while he had some claim to the former denomination, there was no doubt whatever that in choosing Professor Roberts-Austen they had chosen one of the most eminent scientific men of the day.

He had also to announce that, in accordance with Rule 10, the following gentlemen would retire from the Council in May next, but were eligible for re-election:—

Vice-Presidents.

Sir William Thomas Lewis, Bart. Sir John G. N. Alleyne, Bart.
Mr. G. J. Snelus.

Members of Council.

Mr. Francis William Webb. Sir Alfred Hickman, M.P.
Mr. J. E. Stead. Sir Edward H. Carbutt, Bart.
Mr. S. R. Platt.

Mr. BEDFORD MCNEILL and Mr. F. SAUER were appointed Scrutineers, and on the completion of their scrutiny reported that the following gentlemen had been duly elected members of the Institute:—

NAME.	ADDRESS.	PROPOSERS.
Andersson, Axel Olaf	Gothenburg, Sweden	Arthur Cooper, David Evans, Herbert A. Swan.
Aznar, Eduardo de .	Bilbao, Spain	William Whitwell, W. B. Dickinson, Sir Lowthian Bell.
Barrett, Arthur George	The Forge, Bradford, Yorkshire	Joshua Harding, H. M. Butler, Arthur Horsfield.
Beesley, William Thomas	42 Norfolk Road, Sheffield	Robert Colver, Arthur Lee, George Senior.
Beijer, Gottfried . .	Malmö, Sweden	A. Greiner, George J. Snelus, James Riley.
Beijer, Lorens . . .	Malmö, Sweden	A. Greiner, A. Tannett Walker, James Riley.

Name.	Address.	Proposers.
Benedicks, Gustav .	Gysinge, Sweden	Thomas W. Sorby, R. A. Hadfield, John D. Ellis.
Berrier-Fontaine, Marc, M.Inst.C.E. .	Indret, par la Basse-Indre (Loire-Inférieure), France	Edward P. Martin, E. Windsor Richards, Sir B. Samuelson.
Brooks, Samuel Herbert	Union Iron Works, West Gorton, Manchester	Henry Webb, Joseph Adamson, Richard Ogle.
Campbell, Duncan . .	Carntyne Engineering Works, Parkhead, Glasgow	William Beardmore, James Riley, David Sturrock.
Charlton, William . .	The Ashbury Railway Carriage and Iron Works, Openshaw, Manchester	Edward P. Martin, Arthur Keen, Sir Lowthian Bell.
Dyrssen, Gerhard . .	Bofors, Sweden	Lars Uno Lindberg, Carl C:son Lindberg, Jonas C:son Kjellberg.
Edwards, Edward Richard	Atlas Works, Sheffield	John D. Ellis, George S. Packer, T. E. Freeston.
Ekman, Johan . . .	Gothenburg, Sweden	A. G. Ljungberg, A. G. Arfwedson, George Senior.
Garrett, William . .	401 New England Buildings, Cleveland, Ohio, U.S.A.	Edward P. Martin, E. Windsor Richards, David Evans.
Grill, Balthazar . . .	Stockholm, Sweden	Thomas W. Sorby, R. A. Hadfield, John D. Ellis.
Hall, John	The Grange, Hale, Altrincham	Samuel Chatwood, Thomas Ashbury, Henry Webb.
Höglund, Otto M. . .	Stockholm, Sweden	Lars Uno Lindberg, Carl C:son Lindberg, Jonas C:son Kjellberg.
Horngren, Hjalmar .	Stockholm, Sweden	Lars Uno Lindberg, Carl C:son Lindberg, Jonas C:son Kjellberg.
Horton, Leonard Wilson	The Grange, Bescot, Walsall	Arthur Keen, Sir B. Hingley, Jabez Lones.
Julin, Albert von . .	Fiskars, Finland	Wm. F. Beardshaw, R. A. Hadfield, George Senior.
Ledingham, John Machray	Manager's Quarters, Royal Arsenal, Woolwich	Sir F. A. Abel, E. P. Martin, R. A. Hadfield.
Lewis, Joseph Slater, Assoc. M.Inst.C.E. .	Salford Rolling Mills, Manchester	Ewing Matheson, Richard Ogle, J. Stephen Jeans.
Longbotham, Jonathan	High Street, Sheffield	Sir David Dale, Henry Simon, Edward P. Martin.
Luckman, Joseph Frank	Hay Mills, near Birmingham	T. G. Richardson, B. G. Wood, B. M. Renton.
Lundeberg, Christian	Forsbacka, Gefle, Sweden	George Senior, Arthur Lee, Albert Senior.
M'Laren, Walter S. B.	56 Ashley Gardens, London, S.W.	David Evans, E. Windsor Richards, Edward P. Martin.
Menzies, James . . .	Phœnix Tube Works, Glasgow	Andrew Stewart, Sir William Arrol, James Riley.

Name.	Address.	Proposers.
Meyjes, Anthony Cornelius	42 Cannon Street, London, E.C.	E. Windsor Richards, S. Vaughan Morgan, W. E. Freir.
Middleton, John Thomas, Assoc. M. Inst.C.E.	Brackley, Northamptonshire	R. Price Williams, Charles Markham, Edward Wadham.
Miller, James Williard	Carnegie Buildings, Pittsburg, Pa., U.S.A.	Edward P. Martin, J. E. Stead, Joseph Torbock.
Nordenfelt, Thorsten Wilhelm	13 Strandvägen, Stockholm, Sweden	E. Windsor Richards, Sir Lowthian Bell, William Whitwell.
Raven, Vincent, Assoc. M.Inst.C.E.	North - Eastern Railway, Darlington	Sir James Kitson, William Whitwell, Sir David Dale.
Sandberg, Christer Peter (Junior)	Palace Chambers, 9 Bridge Street, Westminster	C. P. Sandberg, Edward P. Martin, Sir B. Samuelson.
Starck, Albert	Stockholm, Sweden	Lars Uno Lindberg, Carl C: son Lindberg, Jonas C: son Kjellberg.
Svedberg, Carl	101 Leadenhall Street, London, E.C.	George Senior, Arthur Lee, Albert Senior.
Tasker, John Henry Royle	6 Highnam Crescent, Moor Oaks, Sheffield	Albert Senior, William Henry Davies, Henry White.
Taylor, Harold J. C.	Endcliffe Crescent, Sheffield	Joseph Gamble, H. Herbert Andrew, Robert Colver.
Thomas, Oswald James	Gwent House, Dowlais, Glamorgan	Edward P. Martin, William Evans (Dowlais), W. Simons.
Waddington, Richard, Assoc. M.Inst.C.E.	35 King William Street, London, E.C.	A. Tannett Walker, Edward P. Martin, E. Windsor Richards.
Warburg, Fredric Samuel	8 Porchester Terrace, London, W.	J. T. Smith, G. H. Müller, F. E. Warburg.
Wedberg, Anders	Nykroppa, Sweden	H. Herbert Andrew, G. E. Hoyland, George Senior.
Worsdell, Wilson, Assoc. M.Inst.C.E.	North-Eastern Railway Locomotive Works, Gateshead-on-Tyne	Sir Lowthian Bell, Edward P. Martin, Sir James Kitson.

The President said the next business was to proceed with the reading and discussion of the papers. The first paper came from the pen of an Honorary Member of the Institute and a Bessemer Gold Medallist (Dr. R. Åkerman), who had enriched their *Transactions* with no less than four papers of great value, and this paper on the "Development of the Swedish Iron Industry" was one that could not fail, in such circumstances as brought them there, to be highly appreciated by the members.

OUTLINES OF THE DEVELOPMENT OF THE SWEDISH IRON INDUSTRY.

By RICHARD ÅKERMAN.

DATING from prehistoric times, the origin of ironmaking in Sweden may be said to be primeval. In Sweden, as elsewhere in those remote times, only malleable iron and steel were produced directly from the ore, and the iron ore then used was no doubt only bog ore. When rock ores were first mined in Sweden is not exactly known, but that such ore was used here in the beginning of the fourteenth century is proved by a charter, still preserved, granted in the year 1303 to "Norbergs jernberg" (the iron mountain of Norberg).

Even the rock ore was for a long time exclusively used for producing malleable iron directly, the so-called "osmund," *i.e.* the name of the unwelded small pieces of iron which were obtained by squeezing together with a sledge-hammer the lump of iron directly extracted from the ore, and cutting it with an axe into pieces, each weighing a little less than a Swedish pound (0·937 lb.). In the Middle Ages, and down to the sixteenth century, these osmund pieces were very commonly used as currency in the absence of the more precious metals, and their production, though in a somewhat modified form, continued so steadfastly, that even after the period when the production of pig iron began in Sweden, more than one hundred and fifty years may still have passed before iron ore mined out of the rock was principally used for producing pig iron. The exact year when the production of pig iron at first began in Sweden is not known, but, to judge from a transfer certificate of stock in the "masungh" (blast-furnace) at Ahmoqvarn, bearing the date of 1461, it may be assumed as certain that the production of pig iron had taken place at that time in Sweden.

It is not known when "Rennwerk," or the direct producing of malleable iron from ore in hearths or bloomery fires, was first practised in Sweden, but it is certain that it was in use at the

time of King Gustaf Wasa (1523–1560). Almost as certain is it that the primitive production of wrought iron directly from the ore, at least for the greater part, was done in very small and frail vertical high bloomery furnaces. The waste of time and labour, as well as of ore and fuel, connected with that old method, must have been enormous, because it is known that only about 170 years ago the daily production of such a furnace in good working order only amounted to about 220 lbs. of osmund iron, from which only 110 to 132 lbs. of bar iron were obtained. In Finland, where eight such furnaces were still in use in 1875, the consumption of charcoal per unit of weight, with this old method of producing bar iron from lake ore, then was about four to five times as much as the consumption now usual in the Swedish furnaces in combination with Lancashire fineries, and nearly seven times as great as in the Swedish blast-furnaces combined with the Bessemer process. As a compensation for these inconveniences, the old direct methods had the advantage that, owing to the low temperature, the reduction became so incomplete that the phosphoric acid occurring in the ore was not, or only to a very small extent, reduced, but entered into the slag as phosphate. Even bar iron produced in this manner from lake ores rich in phosphorus was almost free from that substance, and thus it was possible, even before the Swedish rock ores, low in or almost free from phosphorus, had begun to be utilised, to produce not only wrought iron, but also steel suitable for arms and tools.

That, with the very moderate requirements of the smiths and armourers of the Middle Ages, the Swedish osmund iron was much valued even abroad is further evident from the fact that the ironworks of the county of Mark in Westphalia, which originally re-worked Swedish osmund in hearths to be used as billets for wire and tools, &c., began towards the end of the fifteenth century to convert pig iron from the district of Siegen into bar iron for similar purposes, and for their new product improperly retained the famed Swedish name of osmund, which name had then for a long time in Germany been given to the bar iron produced there from real Swedish osmund.

On the other hand, it is true that complaints of non-uniformity in the osmund iron were by no means unfounded. In the first part of the sixteenth century King Gustaf Wasa therefore left

nothing undone, not only to have the osmund iron refined and forged into bar iron before exportation, but also, and still more, to substitute the combination of the blast-furnace and open fire for the old direct method. Nevertheless, the desired improvements made very slow progress, and, as far as may be seen from a very exact list of tax receipts of the year 1557, the Swedish make of pig iron was not quite a half of the osmund then produced.

Carl IX. and Gustaf II. Adolf continued the efforts of their father and grandfather, and in 1635 the Government even went so far towards accomplishing their object as to put on an export duty on unhammered osmund. However, it was only towards the middle of the seventeenth century that, compared with the gradually increased production of pig iron, the direct conversion of ore into wrought iron had become insignificant enough not to be mentioned any further in the official reports of the iron industry of that time. However, it is known that in certain very remote parts of the country osmund iron, though in rather small quantity, was still produced from bog ore up to the end of the last, and in very exceptional cases even at the beginning of the present, century; and in the description of his travels in Dalecarlia in 1734, Linnæus tells us not only that wrought iron continued to be produced there in small high bloomery furnaces, but also that rich magnetic ore from Bispberg there was still directly converted into wrought iron by "Rennwerk" in bloomery fires.

After the middle of the seventeenth century, when, as has already been shown, the production of pig iron combined with fining in charcoal hearths practically had been completely substituted for the old method, there followed a period of about 180 years in which, compared with that of other countries, the iron industry of Sweden held a relatively higher position than in any other period, and more particularly than the following. At that time the bar iron produced in the manner described became the principal article for export of Sweden, and the demand for Swedish iron in other countries was at that period incomparably greater than before, and still more so than subsequently. And there is no doubt that the iron industry of Sweden in the eighteenth century, in spite of the harassing wars, &c., might have risen to a still

greater importance, if its quantitative growth had not been so closely limited by regulating ordinances having for their object the checking a reckless and improper competition or over-production. But to those ordinances we are at the present time indebted for the advantage that the woods in the mining districts have not been ruined to the extent they no doubt otherwise would have been.

When looked upon from a modern point of view, the iron industry of Sweden in the eighteenth century was very insignificant; but during the greater part of that time, or as long as to the end of the 1780 decade, it was more considerable than that of Great Britain, and during the two decades of 1720–1740, about twice the production of the latter country, and, besides, I have no hesitation in saying, there scarcely was any country at the end of the 1780 period that could present a more considerable iron industry than Sweden.

The causes of the comparatively prosperous state of the Swedish industry during that period are not difficult to find. They were exclusively due to the abundance not only of iron ores practically free from phosphorus, and of woods from which charcoal might be obtained, but also of water-power, or just the three conditions on which a successful iron industry was entirely dependent during the greater part of the seventeenth and eighteenth centuries, with the methods then employed for producing iron.

At that time, ores low in phosphorus were indispensable, for otherwise wrought iron produced from pig iron by hearth-fining became phosphoric, and thus more or less liable to have a crystalline texture, with its consequence—cold-shortness.

Before Darby in England, in 1735, began to use coke in blast-furnaces, no other fuel than charcoal and wood had been practically used in the iron industry. Besides, it must be added, not only that for hearth-fining, which, as is well known, was the only way of converting pig iron into wrought iron until Henry Cort, in 1784, invented the puddling process, charcoal is necessarily required to prevent the producing of a marked red-shortness as a consequence of the absorption of sulphur into the iron, but also that pig iron prepared with coke will not be well adapted for hearth-fining, as, in order to avoid too high a percentage of

sulphur, it must be produced with so great a smelting heat as to become too rich in silicon to be fined advantageously in a hearth with charcoal without a refining previous to the fining. Thus, the iron industry of this period was completely dependent on the supply of charcoal, and, as everybody knows, it was just the cutting down the woods in the densely populated country of England that caused the decadence of its formerly flourishing industry until the secret was found out of making use of fossil fuel, not only for the production of pig iron, but also for the fining.

Before, in the last decades of the eighteenth century, steam-engines began to be used for the service of the iron industry, water-power exclusively constituted the motive power in all iron-works, and the numerous rivers of Sweden were then taken advantage of as offering ample opportunities for building the almost innumerable small ironworks that in this period were erected in the southern central part of Sweden, especially in the neighbourhood of the mines.

The promotion of the Swedish industry in the latter part of the eighteenth century was still further aided by the institution, in 1747, of the Association of Swedish Ironmasters, "Jernkontoret," which was founded on the initiative of Mr. Backmansson, afterwards raised to the peerage under the name of Nordencrantz; and I think the members of this Institute will have an opportunity of seeing that the said Association, "Jernkontoret," is up to this very day exercising an influence and an activity of use in many respects.

In the latter part of the decade of 1780, the employment of Swedish iron abroad began to be restricted, and this state of things became more and more general until, at the present time, it is only for the most important purposes that foreigners can afford to buy our more costly iron. At that time puddled iron began to be made use of in England, replacing Swedish iron, which was no longer employed for unimportant purposes the effects of which were so much the more felt as, with the fining methods then applied in Sweden, it was not possible regularly to produce wrought iron of the same uniformity of softness, and as suitable to certain manufacturers, as the iron then produced in Lancashire and South Wales by another method of hearth-fining combined with re-heating furnaces. The compe-

tition, however, was not yet so alarming, for the puddling on a sand-bed then used required a brand of pig iron rather low in phosphorus, in case the product should not become cold-short. But the chances for Swedish iron became less favourable still when, in 1820, the puddling process used in England began to be improved by Rogers' invention of lining the puddling-hearth with ferrous slags, by means of which it was possible not only to get a product less slaggy than that on the sand-bed, but also to eliminate the greater part of the phosphorus contained in the pig iron, absorbed as it was as phosphate by the basic slag resulting from the basic lining. The consequence was that iron ores with a much larger percentage of phosphorus than had been thought possible before began to be used, and of course the Swedish iron industry then for a great part lost its former superiority.

These three inventions made in England, that of Darby to use coke in blast-furnaces, and those of Cort and Rogers to convert pig iron produced with fossil fuel into wrought iron in reverberatory furnaces without making any use of charcoal, caused the greatest revolution ever experienced in the iron industry; and this transformation was still further promoted by the discovery made in 1828 by Neilson, that hot blast within blast-furnaces, and especially those using fossil fuel, effects a saving of fuel quite unthought of, and even makes it possible to use directly non-caking coal in the blast-furnace. The immediate consequence of these inventions was that development on a large scale of the iron industry of Great Britain which started in the middle of the decade beginning 1780, and as early as 1790 superseded that of Sweden. Other countries, rich in coal, though only about half a century later, followed the example given by England and Scotland. By these circumstances Sweden, which may be said practically to have no coal of her own accessible for her iron industry, and therefore only produces charcoal pig iron, and consequently a rather expensive wrought iron, has been irremediably left behind with respect to the quantity of the production of iron. As, because of its high price compared with those of the coal irons of foreign countries, the Swedish charcoal iron began to be replaced from purposes more easily satisfied, it was so much the more necessary to improve its quality, making it answer the

claims of the time, that it might not only boast of being free from impurities, cold and red shortness, but, with respect to uniformity, also match with the most excellent kinds of iron, and thus become a suitable material for the most exacting requirements.

The Swedish iron, as it still was produced at the beginning of the decade of 1830, was not very fit for these purposes. The German mode of procedure, introduced into Sweden more than three centuries earlier in conjunction with the production of pig iron, had developed many modifications, and constituted the Swedish hearth-fining then usual. But except the German hearth-fining, there were at the time in question only used two others, of which one was likewise introduced from Germany and available for producing hearth raw steel, and the other, the Walloon fining method, introduced from Belgium in the latter part of the seventeenth century by Louis De Geer. This process is still in use for converting the Dannemora pig iron into bar iron for first-class steel, and has in Sweden never been used for anything else. Though the first and last mentioned methods of fining of pigs, with nearly no impurities, gave a wrought iron that was very suitable not only for the general use of small blacksmith-work, but also, when prepared from pig iron of ores very low in phosphorus, constituted the most excellent stock for making blister-steel, still the bar iron made after these methods was of very unequal temper, which greatly diminished its sale to many branches of manufacturing then starting.

At a time when steel was a very rare article, the steely nodules dispersed in these kinds of iron often were of great use by making the final product less subjected to wear and tear, and besides, owing to the distributive effect caused at the cementation process by the long-continued glowing heat on the carbon contained in the hard nodules, produced a blister-steel still more uniform than that prepared from thoroughly soft iron, which at the cementation absorbed its carbon only from without, but on the other side they also caused very great inconveniences in many a manufacturing industry by an increased condemnation. Then, if the Swedish bar iron should any longer find a ready market among such manufacturing industries, it became indispensable, at least partly, to adopt another method capable of pro-

ducing iron of greater uniformity. The man who most clearly saw what was needed and best understood how to remedy the deficiencies was Gustaf Ekman, who, after studying at Ulverstone the charcoal hearth-fining then used there, in 1830 began his experiments in Sweden.

Even with this method of fining, which in Sweden has been called the Lancashire hearth fining, it was not possible to get with certainty an equal temper unless the reheating of the blooms produced with it took place in a reverberatory furnace. Besides, the change for this method of reheating was necessary in order to replace with rolling the hammer-forging exclusively used up to that time, which was not only more expensive than rolling, but also produced a bar iron with cross sections less uniform than had gradually become more and more desirable, not to say indispensable, for many manufacturing purposes. However, the reheating furnaces for coal used in England could not be thought of; for, with the poor means of communication of the time, the price of the English coal was much too high in the Swedish iron-producing districts for such a purpose, and the new method of fining therefore advanced only very slowly, until in the middle of the period, 1840–1850, when Ekman had finished his two types of gas-reheating furnaces, one of which was for charcoal and the other for wood. The former of these furnaces, which, owing to its form, has been called Coal Tower Furnace, has been of inestimable value to the Swedish iron industry, not only in consequence of the great saving in fuel with it from the very beginning of its introduction, but also because of its being so constructed that, when the building of railways had so far advanced in the country in the period 1860–1870 that English coal could be obtained at Swedish works at prices lower than those of charcoal and wood, it might easily be modified so as to be as available for coal as for charcoal, on account of which circumstance it is still the most used type of reheating furnaces in Sweden.

The great saving of fuel effected by Ekman's reheating furnaces was by no means due only to their being gas-furnaces. What also very much contributed to it was their combination of the hearth with a heating chamber, by which arrangement it was possible to make a much better use of the heat of the waste

quantities of iron ores free or almost free from phosphorus are to be found, but where a sufficient supply of coal of its own necessary for its ironworks is lacking. Consequently the puddling process in Sweden was only used for a few purposes for which its products were more suitable than those of hearth-fined iron, as, above all, for the production of axles and plates, but even in this respect it has been almost completely replaced by the open-hearth and Bessemer metal.

In order to take full advantage of the almost complete absence of sulphur in the charcoal, the necessity of paying careful attention to the roasting of the iron ores was early and more keenly felt in Sweden than elsewhere, even for ores containing very little of pyrites. To this may be added the wish to make use of iron ores comparatively rich in pyrites, which ores could not be used without the risk of producing a red-short iron or steel, unless the roasting was made more even and complete than was possible with the old methods by which the roasting was effected in piles or pits. This was so much the more necessary as the methods of hearth-fining used in Sweden did not allow of such a large proportion of silicon in the pig iron as will generally be the case in coal-bearing countries where the sulphur is kept low by the intense heat of the blast-furnace.

If, without the use of manganiferous ores, pig iron very low in silicon and sulphur is regularly required, which is necessary to our methods of fining in charcoal hearths, if the iron treated according to these methods shall be perfectly suitable to the most demanding purposes, the proportion of sulphur contained in the charge of the furnace must be very small. For these reasons the officials of the Jernkontor as far back as 1820 constructed several types of roasting-furnaces, of which two especially have offered considerable advantages until they were replaced by gas-furnaces, the first of which was designed by Starbäck in 1840. The gas-furnaces, gradually improving, reached their perfection in the one designed by Westman in 1851, which, ever since the sixties, has been generally used at the Swedish blast-furnaces, and which has made it possible to profitably use many very pyritic iron ores, formerly considered to be of no account.

By the invention of the Bessemer in 1855, and the Siemens-Martin processes about ten years later, a new era, indeed, was

opened to the iron industry in common, and these remarkable methods are also the cause of great revolutions in the iron industry of Sweden; but in the shape they appeared until 1880, they scarcely exercised any essential influence on the state of the Swedish iron industry compared with that of other countries. Sweden was, indeed, one of the countries that first introduced these two processes, and, as may be observed, the Bessemer process might, perhaps, never have reached its perfection, if Consul G. F. Göransson had not, in the summer of 1858, at Edsken, by increasing the area of the tuyeres, and consequently augmenting the volume of blast, at last succeeded in shortening the process, so as to produce a sufficient heat in the converter to allow of the proper separation of the slag from the metal, and thus also to convert our pig iron, free from impurities, into a good steel, which, having been exported to England, inspired the capitalists who were backing up the late Sir Henry Bessemer. Nevertheless, the transition from Lancashire-fining to the new methods has been comparatively slow; and, as has already been shown, it was only in 1895 that the Swedish production of Bessemer (97,320 tons), and of open-hearth ingots (99,259 tons), altogether (196,579 tons) surpassed that of finery blooms and puddled bars (188,726 tons).

The expectations inspired by the introduction of the Bessemer and Siemens-Martin methods into the country, that Sweden would derive great and special advantages from them, because of her good supplies of ores nearly free from phosphorus necessary for these methods of production, as they were applied at that time, were mostly defeated by the enormous deposits of such ores that were discovered and made available in several other countries in consequence of the increasing wants.

As had been the case with the Lancashire iron, so it now was with the Bessemer and open-hearth products; Sweden had to be contented with the export of only such kinds of iron and steel as were needed for the most delicate purposes, among others even such for which the use of crucible steel had been necessary. For structural purposes and railway-building, which absorb the greater part of the iron and steel produced in other countries, the Swedish ingot metal, as well as wrought iron, owing to the want of cheap

fuel, became too expensive to be used to a greater extent not only abroad but even in our own country.

Our situation, however, was comparatively good, as long as, owing to our material being relatively purer, and consequently less in need of manganese, we more easily than other countries could not only produce soft ingot iron, but also hope for the exhaustibility of the strained supplies of iron ores nearly free from phosphorus. But this state of things became quite changed when, at the end of the seventies, Messrs. Thomas and Gilchrist began using basic lining (dolomite or magnesite) in the Bessemer converter and in the Siemens-Martin or open-hearth furnaces. By this, as is well known, the same advantages were attained as by the puddling-furnaces, being lined with basic lining about 1820, namely, that the phosphorus of the pig iron, by the aid of such linings, could be eliminated as phosphate in the basic slag. The consequence of this has been that the supply of ores low in phosphorus, which had before been necessary for the production of ingots, is comparatively not so pressingly needed any longer, so much the more as, owing to the fact that lime is a much stronger base than the oxides of iron, the dephosphorisation can be effected far more completely in the production of ingot metal in a basic lining than is possible in the puddling process. As, further, the dephosphorisation must be preceded by the decarburisation of the metal, the basic methods are principally suitable for producing iron low in carbon. Thus the Swedish iron was rivalled in producing basic Bessemer, and, still more, open-hearth iron, and the opportunities, already limited, for selling the Swedish iron in the markets of the world were thus still further reduced.

As has already been shown, the Swedish iron industry has, more than by anything else, been injured by those encroachments upon its old privileges of good supplies of ores very low in phosphorus, or even almost free from that impurity, which was caused by the above-mentioned processes of dephosphorisation; and now the Swedish iron industry may be said to have its, perhaps, most essential advantage of those of foreign countries in the comparatively great supply of charcoal, for by means of it and of iron ores well roasted, the sulphur may be next to completely got rid of in the blast-furnaces. Consequently, it is possible, too,

to produce pig iron almost free from sulphur without the overheating of the furnace, and the great amount of silicon in the iron combined with such a proceeding, whereas in countries in which the iron industry is limited to sulphurous fuel, it is difficult, without the aid of manganese, to get pig iron, with respect to the amount of silicon, quite suitable for the basic methods so free from sulphur as is needed for rather delicate purposes.

In this connection I may be allowed to observe that white Swedish pig iron on no account contains sulphur as a rule, as is the case with the coke iron, but there is a belief, based on circumstances quite different from ours, which often causes our foreign customers, accustomed to coke iron and wishing to have Swedish pig iron extra free from silicon, to advance so extravagant a claim as, for instance, to get grey Swedish pig iron with 0·2 per cent. of silicon at the utmost. Pig iron so low in silicon will be principally white, but, if prepared with charcoal from a charge duly free from sulphur, it will nevertheless contain almost no sulphur. Thus, every one wishing to have Swedish pig iron with silicon extra low and almost free from sulphur should give up his demand for grey iron, but, in order to avoid too high a percentage of sulphur, should stipulate that the pig iron must not contain a larger proportion of sulphur than 0·02 to 0·03 per cent.

At the same time as our iron industry, as has already been said, is, especially nowadays, mainly backed up by our supply of charcoal, the greatest obstacle to its progress is, on the other hand, to be found in the complete absence of mineral coal in our mining districts. By this, as shown above, we are limited to the production of iron of comparatively expensive quality, and our competing in quantities at large in the market of the world is never to be thought of. Except for the best kinds of steel required for the production of tools, Swedish iron is now only used for sundry things, such as horseshoe nails, certain kinds of wire, fine harness-mountings, and the like, and when such uses as, some time ago, the crinoline steel and lately cycle spokes were added, the Swedish iron industry entered another and more prosperous stage with advanced prices. The consequence has been that, for keeping the foreign market to Sweden, it has been

found necessary by all means to furnish products more and more uniform in temper, free from impurities, and in every respect better than ever.

In such circumstances, of course, a good deal of attention has been bestowed on the management of the blast-furnaces, as a proof of which it may be pointed out not only that until thirty years ago all guns in Sweden were cast directly from the blast-furnace, but also that, ever since the introduction of the Bessemer process, the pig iron used for it has been taken directly from the blast-furnace into the Bessemer converter without remelting or even without the use of any mixer. The giving up of this method of gun-making in 1868, and the passing over at that time to the remelting in reverberatory furnaces, was not due to a lessened confidence in the former method of production, but to the difficulty of getting sufficiently large quantities of pig iron for producing heavy guns in the old way.

The fact that, because of the comparative costliness of the materials needed for its production, the Swedish Bessemer metal could not be used for such comparatively common purposes as rails and the like, for which the Bessemer metal has for a long time been almost exclusively used in most other countries, caused a very slow progress of the Bessemer process in Sweden in quantitative respect, as the Swedish Bessemer works had all from the beginning been compelled to limit their production to the supplying of very delicate wants. The whole character of our Bessemer industry has accordingly got a stamp quite different from that of other countries, inasmuch as pig iron still lower in sulphur and phosphorus, but at the same time somewhat richer in manganese and lower in silicon, is here used than is usual in other countries. With the lower proportion of silicon contained in our pig iron, and the because thereof less intense heat of the bath, the Casperson converter-ladle is connected, and this apparatus, which is in use at most of the Swedish Bessemer works, facilitates the possibility of effecting the casting without any risk of waste at a temperature favourable with respect to avoiding the dangerous blowholes in the metal, for the exploration of which temperature we are greatly indebted to Mr. C. A. Casperson.

A consequence of our Bessemer pig iron being so free from

sulphur, and generally containing a certain amount of manganese, up to 4 to 5 per cent., is further that the addition of manganese at the end of the process is used in a far more moderate extent in Sweden than in other countries. The process commonly is more directly finished by using less admixture for re-carbonisation than abroad, and for that purpose the same pig iron is often used as that for the Bessemer process itself, to which a comparatively small portion of ferro-manganese is added. What has been said of the Bessemer method may also be applicable to our open-hearth process, but except working pig iron very low in phosphorus, basic open-hearth too has been introduced for the treatment of phosphoric pig iron containing from less than a tenth to 0·5 per cent. of that impurity. The basic open-hearth process is now in use at several works, but the basic Bessemer only at one place. The Table II. will show the development of these two basic methods in Sweden for the last five years.

TABLE II.—*Ingot Iron and Steel produced in Sweden by the Acid and Basic Processes.*

Year.	Bessemer.			Open-Hearth.		
	Acid.	Basic.	Total.	Acid.	Basic.	Total.
	Met. Tons	Met. Tons.	Met. Tons.	Met. Tons.	Met. Tons.	Met. Tons.
1893	75,979	8,419	84,398	66,841	15,048	81,889
1894	72,368	10,954	83,322	68,713	15,290	84,003
1895	79,496	17,824	97,320	79,241	20,018	99,259
1896	92,445	21,675	114,120	102,184	40.117	142,301
1897	81,306	26,373	107,679	118,393	47,443	165,836

In connection with our open-hearth industry, the very high degree of development of the Terre Noire method in Sweden may be mentioned, as for the last twenty years, more and more heavy guns and the like have been produced at Bofors and Finspong from open-hearth castings tempered in oil, which may well compete with the best produced from forged metal. This development is mainly due to Mr. C. Danielsson. Mr. C. Wittenström also deserves to be especially mentioned as the inventor of the important method of producing sound steel castings by the addition of aluminium.

The iron manufacturing of Sweden may indeed boast of a very ancient and illustrious lineage, for already as early as in the first half of the eighteenth century such a celebrity as Kristofer Polhem contributed very much to the progress in this respect, and at the end of the same century the great Sven Rinman was working for the same purpose at Eskilstuna. Nevertheless, in the present century, as long as up into the 1880 decade, Sweden was more and more left behind. After that time a notable change for the better has taken place, and now there are a great many Swedish ironworks which not only produce rolled metal of quite another quality than the common bar-iron of old, but also themselves manufacture more or less of their own production of iron. Sandviken especially is renowned for its excellent as well hot as cold rolled and cold drawn products, and also Munkfors deserves being mentioned in this respect. For the successful efforts of raising the Swedish iron industry by manufacturing, ought likewise to be named as well the principal proprietor of Fagersta, and the reformer of these works, Mr. Chr. Aspelin; as also his eminent assistant, Mr. T. A. Brinell, who has the merit of having given us a good insight into the right manner of treating steel by his very explicit and thorough experiments.

No such inventions in the iron industry as have a revolutionary or world-transforming character can be said to have been made in Sweden. We must be contented with the far humbler testimony of having wisely modified, according to our own wants, the great inventions considered to be useful even to our own iron industry. In the department of scientific metallurgy, however, we have had several eminent leaders, among whom, besides the above-mentioned Sven Rinman—whose fundamental works, "Essay on the History of Iron," 1782, and "Dictionary of Mining," 1788, were for almost half a century the principal iron metallurgic works of the world—may be named Torbern Bergman, who died in 1784, and who gave the inducement to our knowledge of the fact, that the difference between pig iron, steel, and wrought iron depends on the proportion of carbon contained in the metal, and that cold-shortness of iron is caused by phosphorus. Such geniuses as Scheele and Berzelius, no doubt, contributed by their most remarkable works, as well as by their example, to the

early influence of chemistry on metallurgy, earlier in Sweden than in other countries, and by his successful efforts of getting simple methods of determinating the proportion of all particular elements in iron, V. Eggertz has become the founder of the modern assay-science. To the development of the mechanical method of testing, K. Styffe has greatly contributed.

In this connection I must not omit mentioning the great service rendered by many of the officials of Jernkontoret to the iron industry, several of whom are to be reckoned among those above enumerated. Finally, among those who have pre-eminently benefited the Swedish iron industry, I must not forget Mr. F. Lundin, the author of the method of condensation, adopted in Sweden when fuels, rich in water, as sawdust, &c., are used in the Siemens furnaces, nor Mr. E. J. Ljungberg, whose continuous charcoal kiln ought to become of very great use in such charcoal-making places, where a constant and large supply of suitable wood is to be found, as especially at our large saw-mills.

The very fact that, by the lack of coal of her own available in her mining districts, Sweden is shut out from all competition in the heavy iron trades, is a cause of our ironworks being rather small and insignificant compared with those of countries where coal is produced. The fuel exclusively used in Sweden, both in blast-furnaces and in fineries, viz. charcoal, is mostly—especially when, as is the case in our country, made of such soft kinds of wood as pine and fir—so sensible to shocks endured in transit, more particularly in reloading, that it cannot be fetched from very remote places without great waste and loss, amounting to some 20 per cent. or more, and such loss must necessarily be endured if it is desired to increase the production without ruining the woods. It may be added, too, that our charcoal is at least 2·5 times as bulky as coke, and so hygroscopic that it is necessary to store it in well-ventilated houses, that not only prevent the charcoal from getting wet, but also admit of its drying if, because of bad weather, it was wet when stored. The coal-house question is rendered still more difficult by the fact that generally the charcoal can only be brought out from the woods in winter, and consequently, if then a part of the country be not favoured with snow for sleighing, no tolerably considerable quantities of charcoal are to be obtained from that place in such a year. Thus, as the

charcoal cannot be continuously fetched from the woods, the coal-houses must necessarily be made so large as to take about three-fourths of the yearly requirement of charcoal, and this, too, causes a great deal of trouble to the great ironworks. Finally, the lack of really cheap fuel obliges us to avail ourselves of water-power for our ironworks, and many such works that, on account of improved communications, might otherwise be run on a larger scale, are stopped in their progress for want of the water-power necessary. In this decade, however, several ironworks have procured a greater supply of power by electric-power transmission from other waterfalls not too far off, and unquestionably such a proceeding opens a future full of hopes to the industrial development of a country like Sweden, which, as has already been shown, was liberally favoured by Nature with waterfalls, often of very considerable magnitude. In the beginning of the present century, and even up to 1830, a small ironwork or blast-furnace formed a characteristic adjunct to almost every waterfall of moderate size in central Sweden, while the larger ones, owing to the difficulty of utilising them, were for the most part neglected. In some far less degree this may still be said to be the case, but even in Sweden the law of evolution has made itself felt as elsewhere, inasmuch as the small works have been gradually shut down, and the production concentrated in a small number of places better situated with regard to communications and natural supplies, and therefore with much greater power of production. This, as well as the manner in which the same law has shown its influence with respect to the number and producing power of the furnaces in use, will be clearly seen by the Tables III. and IV. The most noticeable is that these changes as to the production per ironwork of malleable iron have occurred faster since the beginning of 1890 than before that time.

TABLE III.

Year.	Quantity of Produced Pig Iron.	Number of Blast-Furnaces in Blast.	Average per Blast-Furnace.		
			Quantity of Produced Pig Iron.	Time in Blast; Days at 24 hours.	Average of Daily Production.
Yearly Average in	Metric Tons.		Met. Tons.		Met. Tons.
1823–32	89,544	299	299	109	2·8
1833	98,964	227	436	156	2·8
1840	124,796	230	543	156	3·5
1850	142,172	228	624	144	4·3
1860	185,894	229	812	134	6·1
1870	300,338	213	1410	178	7·9
1880	405,713	193	2061	210	10·0
1890	456,103	154	2962	246	12·0
1895	462,930	146	3171	252	12·6
1896	494,418	140	3532	271	13·0
1897	538,197	144	3737	286	13·1

TABLE IV.

Year.	Quantity of Produced Wrought and Ingot Iron and Steel.	For the Conversion of Pig Iron into Wrought and Ingot Iron and Steel.		Average Production of Running	
		Number of Iron-works Running.	Number of Hearths and other Fining Furnaces Running.	Ironworks.	Hearths and other Fining Furnaces.
	Metric Tons.			Metric Tons.	Metric Tons.
1833	67,795	...	1190	...	57
1840	87,547	...	1347	...	65
1850	96,890	...	1301	...	74
1860	137,201	...	1260	...	101
1861	151,843	428	987	355	154
1870	205,986	381	864	541	238
1880	256,965	280	765	918	336
1890	361,502	202	618	1790	585
1895	385,305	144	447	2676	862
1896	444,817	136	427	3271	1042
1897	463,147	130	417	3563	1111

No Swedish ironwork was from the beginning planned on a larger scale than the one built at Domnarfvet during the years 1873–1875, and the president of this establishment, Mr. E. J. Ljungberg, has proved better and more clearly than any Swede

how essentially the manufacturing cost per unit of production may be reduced even in this country by carrying on the manufacturing on as large a scale as our circumstances will admit of.

The fact previously mentioned that the Swedish iron never had any market abroad for those purposes which, as rails and other building or structural requirements, both absolutely and relatively demand the largest masses of iron, and the other fact likewise hinted at that the use of it in foreign countries for small blacksmiths' wants was gradually limited to purposes demanding higher and higher quality, may lead to the assumption that the sales abroad of Swedish iron have decreased. Comparatively speaking, this may be true; but fortunately the absolute figures of export prove quite the contrary. That, as is clearly shown by the Table V., the sales abroad of Swedish iron and steel have increased in the present century, is, besides many others, a good testimony of the enormous development of civilisation during this century; as, no doubt, it is to that evolution we must attribute the fact that for only a few and comparatively very small articles, far more iron is required nowadays than was the case with almost innumerable purposes some sixty years ago. The said table will also give an idea of the relatively small importance to Sweden of the foreign market in the present time compared with days of old; for, though the figures of export of malleable iron have been nearly quadrupled since 1833, our present export of such iron amounts to scarcely more than 45 per cent. of the total production; whereas in 1833 the proportion was 88·5. As is shown by the Table V., our production of iron has increased still more rapidly than the export of it, and the difference in these respects will give an idea, though a very faint one, of the increase in the consumption of iron in the country, as in this consumption cast iron, rails, structural iron, and other iron intended for construction or building purposes, imported from other countries, especially the United Kingdom, also ought to have been included.

TABLE V.—*Export of Ingots, Blooms, Bar-iron, Wire-rods, Tubes, Plates, Nails, and Bar-ends.*

Year.	Quantity of Produced Wrought and Ingot Iron and Steel.	Export.	Export in Percentage of the Production of Wrought and Ingot Iron and Steel.
	Metric Tons.	Metric Tons.	
1833	67,795	60,039	88·56 per cent.
1840	87,547	75,097	85·78 ,,
1850	96,890	81,715	84·34 ,,
1860	137,201	102,544	74·74 ,,
1870	205,986	163,112	79·19 ,,
1880	256,965	192,274	74·82 ,,
1890	361,502	225,249	62·31 ,,
1895	385,305	220,163	57·14 ,,
1896	444,817	235,630	52·97 ,,
1897	463,147	209,756	45·29 ,,

In conclusion, referring to some purely technical questions, it may be observed that the economy in fuel realised in the blast-furnaces in the last decades is rather trifling compared with what was attained by the introduction of hot-blast about 1830, in 1840–1850 by raising the stacks of the furnaces, which up to that time had been very low, and by generally substituting two, or sometimes four, for the single tuyere previously employed. It is true that, since the latter date, a continuous increase in height of the furnaces, particularly in 1860 and the beginning of 1870, and a further increase of the temperature of the blast were followed by an increased economy in fuel, bringing down the consumption of charcoal per ton of pig iron a little, but in the last forty years the whole reduction scarcely amounted to more than 7 or perhaps 8 per cent., which, no doubt, is due to the fact that the production of forge pig iron for the Lancashire finery has, in this period, been largely replaced by pig iron for the Bessemer and open-hearth processes, which requires a much greater smelting heat, not always attained by an increase of the temperature of the blast alone. To the last-mentioned fact has contributed the circumstance that, from reasons already mentioned, we are limited to very small quantities of production, it being evident that, because of their heavy sinking-fund charge, expensive arrangements for saving fuel or labour cannot be applied to small establishments so advantageously as to those with a large production.

Dimensions of Blast-Furnaces now used in Sweden.

Height	11–18	metres	(36 to 59 feet).
Diameter of the hearth (at the tuyeres) .	1–2·1	,,	(3½ to 8 feet).
,, ,, boshes	2·2–3·1	,,	(7¼ to 10¼ feet).
,, ,, top	1·5–1·9	,,	(5 to 6¼ feet).

The capacity of the blast-furnaces is 27 to 100 cubic metres. The temperature of the blast varies from cold, which however is very seldom used, up to 800° C., but is generally kept at 200° C. for Lancashire pig, and at 300°–400° C. for open-hearth and Bessemer pig. Only the furnaces at Björneborg and Domnarfvet are provided with regenerative hot-blast stoves, producing a temperature of 700°–800° C. The consumption of charcoal per ton of pig iron is from 4·8 to 8·2 cubic metres, generally amounting to about 6 cubic metres. As only charcoal made of fir and pine is used, and this in ordinary air-dried condition does not weigh more than 140–160 kg. per cubic metre, and only contains about 82 per cent. of fixed carbon, the consumption of real carbon per ton of pig iron may be estimated at 0·590 to 1·010, or mostly, about 0·740 tons. The average production per furnace in 24 hours, as shown by the Table III., was in 1897 13·1 tons, and only at Domnarfvet figures as high as 40–45 tons per 24 hours were reached.

As for the Lancashire fining, the production per hearth has been doubled or trebled in the course of time, and the consumption of charcoal has been reduced in a corresponding degree. To this happy result, besides other circumstances, as especially larger hearths, the machine-breaker, invented by Mr. Y. Lagervall, has greatly contributed. Now the weekly production per hearth generally amounts to 14–20 tons of blooms, with a waste of 7 to 15 per cent., and a consumption of 2·5 to 4 cubic metres of charcoal per ton of metal charged.

For the Bessemer process, as has already been said, the pig is taken directly from the blast-furnace, and the silicon contained in it is generally 1 per cent. or a little more, but commonly it also contains 1 to 5 per cent. of manganese. The blowing-time varies from 5 to 20 minutes, being as a rule less than 10 minutes, and the waste is from 8·75 to 12 per cent., usually about 10 per cent.

DISCUSSION.

Sir JAMES KITSON, Bart., M.P., Past-President, said he was sure they were all deeply interested, and indebted to Dr. R. Åkerman for the very able review which he had given them of the history and position of the Swedish iron trade. They recognised in that paper that it was owing to the care with which chemistry and its scientific application to practical work, through the instrumentality of such men as Richard Åkerman and those who had preceded him, that the Swedish iron trade had been able to maintain the position which it had held and continued to hold in the eyes of the world.

It had been said by his Excellency the Governor that the Swedish iron trade held but a humble position in the trades of the world. Well, for his part, as one who had been engaged in what was now sometimes termed a fossil manufacture, one of the relics of the past, the manufacture of high qualities of Yorkshire bar iron, he was free to make his acknowledgments to the producers of the pig iron of Sweden for enabling them from time to time to improve the qualities of English iron by the addition to their mixtures of those pure brands of Swedish iron for which they were so celebrated. He must say that he did not take the view which Dr. Åkerman had propounded, that there was a chance of Swedish iron being in diminished demand. For the manufacture of steel in its application in great masses to all the methods of construction of buildings, of ships of war, of implements of war, steel of the highest quality was necessary. In these developments they would see a great demand for the higher qualities of steel would be created, and as the base was expanded so the summit might grow, and he was satisfied that there was a great field for the pure qualities of Swedish iron in the developments of the application of that metal to all the arts and sciences of the world.

Their course as Swedish iron manufacturers was absolutely clear, viz., to take care, through their Jernkontor and their other institutions, that Sweden only produced material of the

highest quality, and for that highest quality the demand was destined to expand. The manufacturers in England met with difficulties which were very great. As their qualities were improved they were surrounded by a group of eminent inspectors and instructed chemists who examined everything they produced with critical care, and when they once reached a record result they insisted by all the means in their power—and those means and those powers were very great—on that highest record being maintained.

But he assured the Swedish iron trade that in many of the highest qualities which were used in England for railway tires and railway axles, for boilers, and other constructions, it was necessary that they should have an admixture of the pure brands of Swedish iron. They knew in other days that the manufacturers of crucible steel in Sheffield were considered to have obtained the basis of their fortune when they had secured the exclusive right to sell or to hold certain brands of Swedish iron. Well, the same thing obtained, in a still higher degree, in these days, and reading this paper, which had placed very clearly before them the progress of Swedish scientific manufacture, he could only say words of encouragement to pursue the course that they had taken in the past under the direction of the admirable institutions which they possessed, so as to give to the world, not England alone, those pure brands of Swedish iron, and Sweden and Stockholm were destined ever to flourish.

Mr. G. J. Snelus, Vice-President, thought they were deeply indebted to Dr. Åkerman, not only for the paper which he had read to them that morning, but for his previous contributions to the literature which they had in the Institute. He had been deeply interested in examining the early traces of iron work in Sweden, and he would have very much liked if Dr. Åkerman could have gone a little more fully into the history of the very earliest portion of the manufacture. No one could go round the city of Stockholm and examine the relics of antiquity in the Zoological Gardens, in the form of ancient buildings, &c., without being struck with the remarkable success which the inhabitants of the country had attained in the manufacture of iron centuries ago. Dr Åkerman did not go back many centuries, but he

sure, feel deeply indebted to Dr. Åkerman for having taken the trouble to give them a record of what had been done in that pioneer country in iron and steel making.

Mr William Henry Bleckly, Vice-President, said there was an interesting circumstance in the paper regarding the Lancashire process which he should like to notice.

English ironmasters often wondered how it happened that iron was imported into England from Sweden branded "Lancashire." This had been a puzzle to them for a long time, and he had repeatedly tried to fathom the mystery. It was clearly no attempt to pass off Swedish as Lancashire iron. His hearers all knew that it would be no compliment to the Swedish iron manufacturers to let it be supposed that their iron was made in Lancashire. Lancashire iron was well known to be of a different grade to Swedish, and Lancashire manufacturers were therefore very much at a loss to divine how the brand of "Lancashire" originated, and why iron came into England so branded, but of much better quality than they could produce. This puzzle was now solved, as he presumed the reason such bars were branded "Lancashire" was because it had been made by the old and interesting Lancashire process described by Dr. Åkerman.

Professor Roberts-Austen, C.B., President-elect, said he had one remark to make. It was not merely that Sweden owed the great excellency of the iron produced to the care which was taken in relation to the chemical composition of the different varieties of iron, but to the care which had been given to the study of the physical condition of the metal. He wished on the part of the English and American guests to bear testimony to the great importance of the work of Mr. Brinell, who was the first, he might safely say, to point to the extreme importance of investigating not merely the chemical properties but the physical properties of iron. The importance which Sweden attached to such questions was brought home to him twenty-eight years ago when he first visited Sweden, and was kindly received by Dr. Åkerman's father, who was then Master of the Mint, and who, by introducing him to certain works where

physical tests were conducted, enabled him to form an opinion as to the great importance of such investigations.

Mr. W. F. Beardshaw agreed with Sir James Kitson that their success in making high-class steel was due to the high quality of the Swedish iron. Both the present and the future of Swedish iron was looked to with far more hope by Sheffield manufacturers than Dr. Åkerman's paper represented to them. It was not only the Swedish bar iron that was proving a great success, but in Sheffield they were making a better and better material from the open hearth, and it was principally due to the high quality of Swedish pig iron that they were able to make such satisfactory quality. On behalf of Sheffield he must give a word of encouragement to Dr. Åkerman, and assure him that the present and future of the Swedish iron industry was looked upon with every hope for its continued success.

Professor H. M. Howe said it was a very remarkable part which Mr. Brinell had played in increasing their knowledge of the constitution and nature of iron and steel. Mr. Brinell had accomplished very great results, which compared creditably with those obtained by any other of the present investigators; and the remarkable thing was, that while the rest of them had had instruments of great delicacy and precision to work with, delicate pyrometers and microscopic arrangements, Mr. Brinell's results had been obtained with the use of nothing more than a blacksmith's forge, his own eyes and brains. This power of obtaining a deep insight into the nature of a subject thus unaided was the mark of a powerful mind and of a very remarkable vision.

The President said Dr. Åkerman's paper had informed them what iron and steel manufacturers owed to Sweden, and the care with which this industry had been fostered by the kings of Sweden from the time of Gustavus Wasa to the present by King Oscar, who encouraged and helped everything connected with the improvement of the material interests of his country. He would remind the meeting that when the Jernkontor was

founded about 1747, the pig-iron manufacture of South Wales was only beginning, and Sweden was then making probably twice as much iron as the whole of Great Britain. He begged them to accord Director-General Åkerman a hearty vote of thanks for his very able paper.

Dr. ÅKERMAN acknowledged the kind manner in which his paper had been received.

The PRESIDENT had very great pleasure in announcing to the members that King Oscar would honour them with his presence about noon on the following day, and he trusted they would then have a good attendance to show how much they appreciated his Majesty's presence among them.

The next paper to be read was that of Professor G. NORDENSTRÖM, who was unfortunately suffering from ill-health. He was the leading authority on this subject in Sweden, and he was glad to learn that the Jernkontor had shown their appreciation of the Professor's twenty-five years of constant work in advancing Swedish mining by awarding him their great Gold Medal. They all wished him a speedy recovery.

The SECRETARY then read an abstract of the paper.

THE MOST PROMINENT AND CHARACTERISTIC FEATURES OF SWEDISH IRON ORE MINING.

By Prof. G. NORDENSTRÖM (School of Mines, Stockholm).

The mining of Swedish iron ores has from its beginning been much influenced by the method of working and mining adopted in the Swedish copper, silver, and lead mines, or principally by the German method, which was long in use in these mines. Indeed, our German neighbours may be said to have been the instructors of most countries in mining. With us, as also in many other countries, mining, however, subsequently developed, in several respects independently, partly through the endeavours of our professional men, most frequently apart from any influence from other countries, partly also, in a certain degree, as a consequence of the nature of our ore deposits and their mode of occurrence, and, in connection therewith, of the geological conditions of the country in general.

In this paper I shall endeavour to present the principal features of Swedish mining in which it differs from that of other countries. By way of introduction, I will give a summary of the geological conditions of our country.

I. Introduction—General Geology.

The geological character of Sweden is, in general, very different from that of other European countries, and this is partly due to the fact that in by far the largest part of the country only two of the geological series are represented—namely, the two extremes, the oldest and the youngest—and partly because the country having been one of the principal centres of the North European land-ice, the deposits which were formed in connection with this glacial period are very largely developed, and give the country its peculiar stamp.

The uneven, undulating rock bottom which, as a rule, belongs

to the archæan series, or primitive rock, is thus usually covered with quaternary deposits, gravel, sand, and clays.

Among the archæan rocks occurring in Sweden, gneiss is the most common. It occurs over enormous extents of country, covering almost the whole south-west part of Sweden, and a very broad belt along the east coast, from Vestervik in the south up to the Finnish frontier in the north. The gneisses are of many kinds. They are red and grey in many different shades, and a large number of varieties are distinguishable, among which the following may be mentioned: hornblende gneiss, corderite gneiss, garnet gneiss, iron-gneiss, &c.

In Southern Sweden the primitive rock is divided into two parts on a line running north to south. The rocks in the west part are quite unlike those in the east. In the west part the rocks are mostly reddish iron gneiss, but in the east part there is a great variation, the granite, "hælleflinta" (petrosilex) gneiss, &c., alternating. Attempts have been made to explain this by presuming that an enormous overthrust has taken place along this line, the west part being sunk in relation to the east part.

In certain portions of the gneiss region of Eastern Sweden, in the provinces of Södermanland and Östergötland, there are stratified deposits of limestone and iron ore, but in the gneiss regions of Western Sweden granular limestone does not occur, with but one exception, neither does it occur in Southern Sweden south of the province Östergötland, with two or three exceptions.

In the gneiss regions referred to granite gneiss, granite porphyry, diorite, gabbro, hyperite, &c., frequently occur, as well as fine-grained rocks, regarded as belonging to the youngest of the archæan deposits. These latter consist of hælleflinta-gneiss or granulite, hælleflinta, quartzite, beds of metamorphosed conglomerates, mica-schists, clay-slate, and granular limestone. From a technical point of view, these youngest archæan rocks are of special importance, since our best and largest deposits of iron ores, as well as those of other metals, such as copper, zinc, lead, silver, manganese, &c., are connected with them.

Granite is found mostly in the south-east part of Sweden, and also in rich massive deposits in several different parts of the country, sometimes connected with the gneisses, and sometimes younger and cutting across them, but still of Archæan age.

and its length about 1800 kilometres. If this supposition is correct, these overthrusts greatly exceed in magnitude the largest hitherto known, namely, those in the Chablais region in Switzerland, which have been shown to have a width of 50 kilometres.

The Mesozoic series is represented by Triassic, Jurassic, and Cretaceous strata, which are exclusively confined to the southernmost province of the country, namely, Skåne or Scania, where the greatest diversity in the geological structure is observed.

In the north-western part of Scania there are layers of sandstone and clay belonging to the beginning of the Jurassic and to the Rhætic period. These are furthermore noteworthy for containing the only beds of coal in Sweden, which are mined at Höganäs, Billesholm, Bjuf, Skromberga, Ljungsgårda, and some other places. The coal occurs mostly in horizontal or slightly inclined beds alternating with carbonaceous shales, and there is generally only one bed which is worth working. The whole thickness seldom exceeds 1·6 metre. Immediately below the coal-bed there is generally a layer of refractory clay, which has a maximum thickness of two metres, and is worked partly or entirely at the same time as the coal-bed.

Among younger eruptive rocks mention should be made of the diabases, which often occur in beds and dykes in the Silurian and other older systems. Nepheline-syenite and melilite-basalt, and the post-cretaceous basalts, only occur in the province of Scania.

The quaternary deposits are either glacial or post-glacial. That most extensively developed is the morainic gravel, which is in places covered with glacial clays of marine origin.

These deposits are characterised by the so-called "åsar," or the elongated ridges occurring here and there, and consisting almost exclusively of sand and layers of glaciated gravel and boulders.

The post-glacial deposits are represented by marine clays and alluvial formations. In the latter there are, in nearly all parts of Sweden, peat-bogs, which altogether occupy an area of about five million hectares (nearly 20,000 square miles). In this connection I should mention the lake and bog ores, which, together with the peat-bogs, are the only Swedish quaternary formations of any great economic value.

[illegible] extended *viâ* Kirunnavara-Luossavara to the Nor[illegible] Ofoten, which is free from ice all the year round.

[illegible] so-called "mountain ores" of the older formations, [illegible] ores of quaternary or recent origin are found [illegible] especially in the province of Småland, but they [illegible] in the provinces of Vermland and Dalecarlia, and as [illegible] less extent in several other provinces.

[illegible] production of these ores has, however, never been very [illegible] and of late it has so decreased that it is now very insignificant.

[illegible] said in the following pages about iron ores, therefore, [illegible] refers to that kind of iron ore called "mountain ore," [illegible] occurs in the primitive formations.

[illegible] the Iron Ores.

[illegible] as bedded deposits. Only a few [illegible] veins or masses.

[illegible] As has already been implied, the iron [illegible] primitive formation, [illegible] hälleflinta (petrosilex), [illegible] are especially numerous [illegible] this mineral is quite [illegible] greatest deposits of iron [illegible] Dannemora, Bisp[illegible] &c.

[illegible] regions are [illegible] mentioned the [illegible] however.

[illegible] that they [illegible] very large. [illegible] in

[illegible] with the [illegible]

[illegible] the waste [illegible] the most

part, entirely different from those which accompany ore in lodes or veins. These minerals accompanying our iron ores, to which are given the name "skarn" or gangues (matrix), are pyroxene, amphibole, epidote, felspar, garnet, talc, chlorite, apatite, calcspar, quartz, &c.

The iron ores seldom occur in isolated lenses, but most frequently appear several together, and it is then not seldom that they form longer or shorter series of lenses occurring in a line, one after the other, or forming two or more parallel lines. The lenses in each series are frequently so placed that each varies more or less from the main longitudinal direction of the preceding one. Since the iron ore beds run in the same direction and have the same inclination as the country, they also follow all its bends and folds. Consequently there are frequently sudden transitions from one inclination or direction to another, and the ores occur in the form of concave, trough-shaped, and saddle-shaped deposits, which are, however, generally more or less denuded. The thickness of the iron ore deposits varies much, partly because of their lenticular form, and partly on account of the dislocations and pressures to which they have been subjected since their formation. The thickness is greatest in the ores of the famous iron mountains in Norrbotten. In Kirunnavara the maximum thickness of the deposit varies between 35 and 150 metres. In Gellivare there are ore deposits with a thickness of 70 metres.

Among the mines of Central Sweden the Grängesberg mine takes the lead in this respect. Here the maximum thickness is 90 metres. In the other large mines it varies from 12 to 30 metres, and sometimes reaches 35 metres. In most mines, however, it is less than 10 or 12 metres. If the deposit has a thickness of 2 metres only, it is still considered worth mining.

In regard to the length of the ore field, the Norbotten ores also take the lead. Thus the great stock-formed deposit at Kirunnavara has an uninterrupted length of 3500 metres, and at the adjacent Luossavara mine the ore has a length of nearly 1300 metres, also uninterrupted.

In the Gellivare ore mountain, also situated in Norbotten, there is not a continuous ore deposit or ore stock of so great a length as that in Kirunnavara, but the total length of the ore lenses here present, together with the intermediate dead rock, is 7000 metres.

In the long-worked iron ore mines of Central Sweden there are not lenses of ore or stocks of ore of so great length as in Kirunnavara. The most prominent mines in this respect are those at Norberg and at Grängesberg. At the former mine there are ore deposits with a length up to 1200 metres, while at the latter mine the maximum length of the deposit is 1000 metres. Deposits 200 to 300 metres long occur in several mines.

If, on the other hand, we take into consideration the total length of the ore field, or of the whole series of deposits following each other in the same direction, we also get very large figures. Thus, the total length of the Norberg ore field is nearly 20,000 metres, that of Grängesberg, together with Lomberg, which belongs to Grängesberg, 4000 metres, that of Riddarhyttan 3500 metres, and that of the world-renowned Dannemora ore field 2000 metres.

Following the inclination, iron ore deposits have been worked to a maximum depth of 400 metres. The Åsboberg mine (the vertical depth is here 280 metres), in Nerike, has been worked to this depth. The mines with the greatest vertical depth are Taberg in Vermland, and Dalkarlsberg in Nerike. The former has a depth of 355 metres, the latter 330 metres. In Marnäs mine, in the Grängesberg ore field, the ore has been worked along the inclination to an inclined depth of 350 metres (285 metres vertical depth). None of the other mines, even those which have been worked since time immemorial, are as deep. In regard to the persistence in depth of iron ores, it may be noticed that in the mines worked to the greatest depth, the ore did not seem inclined to decrease, but it has generally the same dimensions as at higher levels.

Resources of Iron Ore in Sweden.—What has already been said about the length of certain ore deposits, and about their thickness, is enough to show that Sweden has very large resources of iron ore. This can be seen more accurately by the following table (I.), which gives in square metres the area of the horizontal section of the ore deposit in some of the larger iron ore mines of Sweden, and the total ore area of the other iron ore fields, approximately calculated.

having sunk. The dip of the vein then varies between 45° and 90°. When the dip of the vein is less than 45° the fault generally takes place in the opposite direction (reversed fault).

Besides the minerals mentioned above, these veins are sometimes composed of quartz, calcspar, epidote, mica, zeolite, felspar, asphalt, clay, &c.

(*c.*) *Veins and Masses of Iron Ore.*—As has been intimated above, there are only a few iron ores which belong to this category. Among these should be classed the iron ores which occur as a kind of vein-masses in certain rocks belonging to the gabbro and hyperite groups. The most renowned of these iron ore deposits is that at Taberg, eleven kilometres south of Jönköping (Småland). It is found here in form of a mountain 125 metres high, 150 metres wide, and about 900 metres long. The iron ores also occurring in hyperite at Långhult, in the same province, and at Ransberg in Vestergötland, are considered to be analogous in character.

The only other iron ore which can be considered as real vein ore is that which has been mined at Hesselkulla in Nerike. The country is here primitive granite.

3. *Nature and Composition of Iron Ores.*

The minerals which constitute the so-called mountain ores are magnetite or black ore, and hæmatite or specular iron. The former is beyond all question the most common. Of the total production of iron ores during the period 1891–95, about 83 per cent. was magnetite or "black ore," and 17 per cent. hæmatite or "blood-stone." In 1897 the former amounted to 89 per cent. and the latter to 11 per cent. Generally one of these minerals constitutes the principal part of the ore. A large number of iron ores contain, however, an intimate mixture of both of these minerals, and sometimes even it is difficult to tell under which mineral the ore should be classed.

Iron ore contains, besides the ore mineral, a large number of other minerals, the so-called "skarn" or waste minerals, which occur in more or less intimate mixture with the ore minerals, and thereby help to give the ore a certain character. Among other minerals, quartz is a very common constituent, especially

Its iron contents vary between 48 per cent. and 52 per cent., and its percentage of titanic acid between 11 and 13.

As regards the aforesaid five groups of ores in general, their iron percentage varies between 30 per cent. and 70 per cent., but generally runs between 50 per cent. and 60 per cent. The ores of the fourth group are sometimes used, even if they do not contain more than about 20 per cent. of iron, but only in mixture with richer quartz ores.

Swedish iron ores generally contain very little phosphorus. The ores most renowned for their low percentage of phosphorus are the Dannemora ores, which contain only 0·002 and 0·003 per cent. of phosphorus, and the ores from Bisberg, Persberg, Rishöjdberg, and Klackberg (in Norberg), whose percentage of phosphorus varies between this minimum and a somewhat larger maximum. Generally the percentage of phosphorus otherwise varies between 0·005 per cent, and 0·05 per cent.

On the other hand, there are ores containing from 0·1 per cent. to 1·5 per cent. of phosphorus, such as, for instance, some ores from Grängesberg, Gellivare, and Kirunnavara. In the two latter ore fields there are also ores containing from 1·5 to 3 per cent. of phosphorus.

The majority of the siliceous specular ores, and even a considerable number of magnetite ores, are very free from sulphur, but most of the Swedish iron ores are, however, so full of iron pyrites or other sulphur ores (magnetic pyrites, copper pyrites, zincoblende, galen, arsenic pyrites), that if a pig iron free from sulphur is to be made from these ores, they must be subjected to a careful calcining.

As an example of manganiferous ores I may mention those at Långvik (Dalecarlia), which contain 10 per cent. of protoxide of manganese, and the Klackberg ores, in the Norberg district (Vestmanland), whose percentage of protoxide of manganese amounts to 7 per cent. There is also the ore from the Penning mine (Gestrikland), which contains 12 per cent. to 14 per cent. of protoxide of manganese, and the ore from Svartberg (Dalecarlia), which is the most manganiferous of all, containing from 13 per cent. up to 20 per cent. of protoxide of manganese.

Fuller particulars of the composition of Swedish iron ores are given in the tables of analyses (Table II.).

III. On the Use of Magnetic Instruments in Exploring for Iron Ore.

In no country have magnetic instruments been employed so long and on such a large scale for discovering iron ores, nor have the instruments used for this purpose in any other country reached such perfection as in Sweden. Some have thought that this depends upon the fact that all Swedish iron ores generally more or less attract the needle, while such ores are less common in other countries. It is also true that not only the most commonly occurring iron ores in our country, the magnetite ores, but also the next commonest, the hæmatites, are magnetic, although in a lesser degree, since they are always more or less mixed with magnetite. But such iron ores also occur, as is well known, in large quantities in many other countries, notably in the United States of America, also in Canada, Mexico, Russia (Ural Mountains and South Russia), Asia Minor, and British India. In several places in these countries there are very large and numerous iron ore deposits, partly composed of magnetite and partly of hæmatite mixed with magnetite. Furthermore, such iron ores occur (although not in such great quantities) in Spain (in the provinces of Malaga, Seville, and in the Pyrenees mountains), in Portugal (at San Thiago, in the province of Alemtejo), in France (in the Eastern Pyrenees mountains at Carrigon, at Segré, in the Department of Maine-et-Loire, at Diélette, in the Department of La Manche), and in Italy (on the island Elba, in Piedmont, and in Sardinia).

Sweden is, therefore, far from being alone in the possession of such ore deposits. Thus the fact that magnetic instruments have long been employed on a large scale does not at all depend upon these suppositions, but can doubtless be ascribed to the interest for the exploring of ore which has made itself manifest for centuries, not only among our mining men, but also among the inhabitants of the mining districts in general. Among the latter class, this interest was aforetime constantly encouraged by the rulers of the country, who granted mining charters and rewards to such as discovered new ore deposits. A law was made to this effect more than 300 years ago.

Magnetic instruments have, in Sweden, been employed for

exploring ore for more than 200 years, and perhaps longer. To begin with, only declination compasses were probably used for this purpose. In 1770 inclination compasses, or what are now called miners' dip compasses, were also brought into use. This miners' dip compass was constructed in the following manner: In a round brass box a magnetic needle is suspended in such a way that it can move freely on a horizontal plane and on a vertical plane to an angle of about 70° from the horizon. It is compensated for the earth's magnetism, so that it takes a horizontal position in districts void of ore, or where there are no magnetic ores. By the help of this simple instrument, which by far excels the dip compass, "invented" a hundred years later (1866) in the United States, all our iron ores have been explored, and even a large number of other ore deposits, such as copper, zinc, cobalt, and nickel, have been discovered by its aid, since these ores contain a greater or lesser proportion of magnetite or magnetic pyrites. As a rule, miners' compasses without graduation are used. The horizontal plane of the needle is only indicated by a ring inside the compass. The dip of the needle is estimated only by the eye, and is not actually measured. The miners' compass is still used, and with success, for exploring for ores, but more particularly for the preliminary exploring work in ore fields.

In later times, however, the demand for more accurate results has grown, and during the past thirty years there have been introduced magnetic instruments, by means of which a still more exact knowledge of the magnetic conditions of our iron ore fields can be obtained. These instruments are Thalén's magnetometer and Tiberg's inclinator or inclination-balance.

Thalén's magnetometer, constructed by Mr. Thalén, Professor at the Upsala University, is a modification of Lamont's theodolite. It consists of a declination-compass (A, Fig. 1) of about 80 millimetres in diameter, which is provided with a scale graduated to degrees and half degrees from 0° to 90°. At right angles to the diameter which passes through the zero-point of the scale, there is attached an arm (B) from 200 to 220 mm. long. On this arm, which is graduated in millimetres, is placed the bar-magnet (C) for the deviation measurements, which can at the will of the operator be given a certain fixed distance from the centre of the

needle. The instrument is rotated on a vertical axis whose central line passes through the centre of the magnetic needle. It is provided with a spirit-level (D), sights (E and F) and levelling-screws, and is placed on a tripod.

Thalén's magnetometer, which has been in use for more than twenty-five years, is now used principally for measuring horizontal

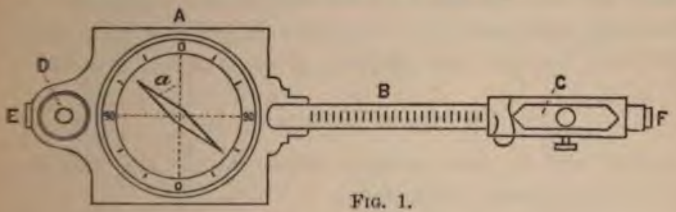

FIG. 1.

intensity. In so doing, two methods may be used; the tangent method and the sine method.

In using the tangent method, the magnetic needle is first placed at zero after the instrument has been levelled and the bar-magnet has been removed from its place. Then the bar-

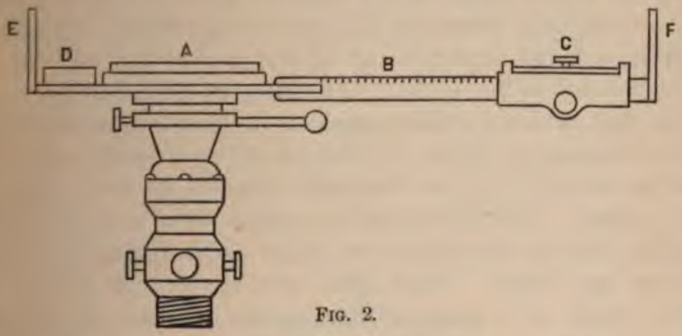

FIG. 2.

magnet is put in its proper place on the arm, and the angle of deviation (a) is read.

In using the sine method, the bar-magnet is first put in place on the arm. Then the magnetic needle is placed at zero, and, after the bar-magnet has then been removed, the angle of deviation (a) is read. This latter method gives more exact results, and it is always used for theoretical calculation or when absolutely exact results are desired. In practice, however, the

tangent method is generally used, partly because it is more convenient and partly because it is everywhere applicable, which is not the case with the sine method in certain points of the ore field north of the ore. In these points the free needle has an indifferent equilibrium, and they are therefore called indifferent points.

If in measurements of a field where magnetic ores are found, R stands for the resultant of the horizontal component of the earth's magnetism and other magnetic forces present, the following formulæ for the two methods of observation are easily obtained:—

$$R \tan. a = K, \text{ and } R \sin a = K_2,$$

in which K and K_2 are constants as long as the size and position of the magnet remain unaltered.

In regard to the use of the magnetometer in ore fields, I have given a more detailed account on pp. 23–25 of my book, "L'Industrie Minière de la Suède," published last year. Referring to this book, I will here only give the main points of the method commonly used.

Before the measurements are begun, the instrument is adjusted at a place where there are no magnetic ores, and consequently no other magnetic force than the earth's magnetism. The angle of deviation found here is noted a_0, and is generally so arranged that it is equal to 25° or 30°. Then begins the measurement of the ore field, which for this purpose is divided into squares with sides 10 metres in length. By the aid of the tangent method the angle of deviation (a) is afterwards obtained in each corner of every square. These a-values are noted on a map (see ideal map, Fig. 3), and the points for which equal angles have been obtained are joined. This gives two systems of isodynamic curves, which in a more or less regular manner are grouped around their foci or centres. One of these is situated north of the ore and where the a-value is greatest, and is therefore noted with a-maximum; the other is situated either directly above the greatest mass of ore or somewhat to the south of it, and represents the smallest a-value, being therefore noted with a-minimum. Between these two groups of curves there is an open curved line, whose angle of deviation is the same as obtained in dead regions and it is noted with a_0. This curved line is called a neutral line after the angle a_0, which is called a neutral angle.

The line which unites the maximum point and the minimum point indicates the direction of the magnetic meridian of the ore field. The centre of the greatest mass of ore is situated in

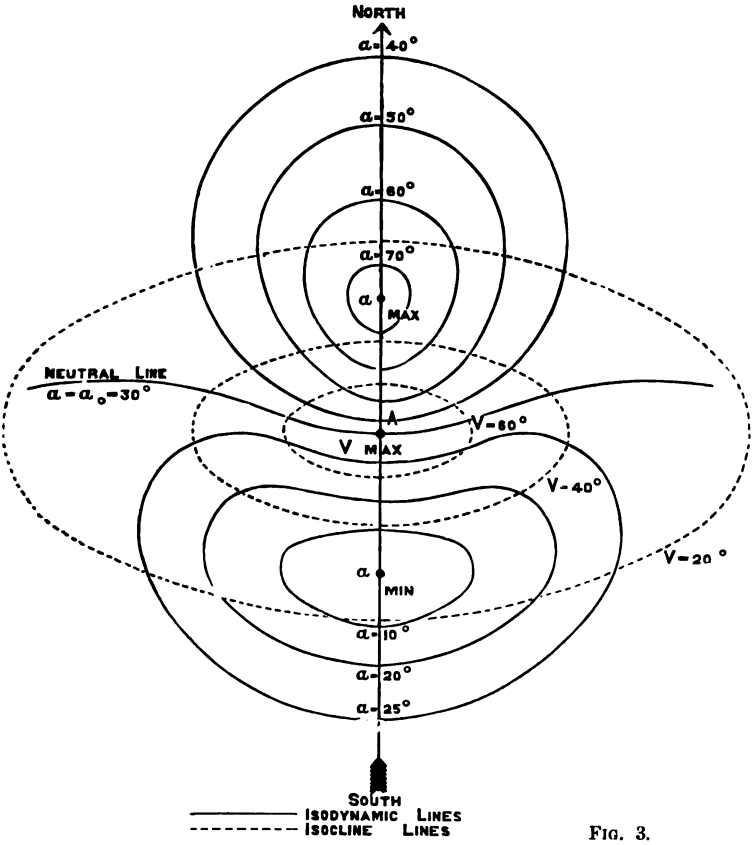

FIG. 3.

the point of intersection of the magnetic meridian and the neutral line as often as

$$\sin \alpha_0 < 3 \sin \alpha_{\text{min.}}$$

In this case the outcrop of the ore is also covered with more or less thick beds of sand, gravel, or other younger deposits.

If, on the other hand, we have $\sin \alpha_0 \geqq 3 \sin \alpha_{\text{min.}}$, the

centre of the ore is situated either under the point representing a min., or somewhere on the magnetic meridian between this point and the aforesaid point of intersection. In this case the ore either crops out at the surface, or its outcrop is covered with younger deposits, whose thickness is less the nearer the centre of the ore lies to the minimum point.

Finally, it should be noticed that, in order to get correct results, the levelling of the ore field which is being measured should be known.

Tiberg's inclinator, or inclination balance, as it is also called, has been in use since 1880, when it was invented by E. Tiberg. It consists of a dip compass, 80 millimetres in diameter, graduated from 0°–90°, and a magnetic needle so hung that it cannot move except on the plane of the graduated circular scale. The instrument furthermore differs from other dip compasses in that the centre of gravity of the magnetic needle is a little below its horizontal axis when the compass is in a vertical position. The needle is compensated for the vertical force of the earth's magnetism by a piece of wax, or by a counterbalance of aluminium fixed to it.

For some years this instrument has been generally used in combination with Thalén's magnetometer, partly to avoid the necessity of taking more than one instrument on surveying expeditions, and partly because that by such a combination of the two instruments, measurements, according to both Thalén's and Tiberg's methods, could be more quickly made, especially if the tangent method was to be used.

The combined instrument is illustrated in Figs. 4 and 5. Fig. 4 shows the instrument furnished with Tiberg's compass, but in Fig. 5 it is substituted by Thalén's compass.

In order to make it possible to use first the one and then the other of these compasses, they are provided with axle-pins fitting into the bearings in the standards (a). The centre-lines of the axle-pins in the Tiberg compass run through the zero-points, but in the Thalén compass through the 90° point. The instrument is furnished with a spirit-level (b), a transverse arm (c), and sights (d). The arm (c), secured on one of the standards, serves to receive the bar-magnet for the deviation measurements, when measurements according to the Thalén method are to be

[illegible]. The method of using the instrument in making such measurements has already been sufficiently explained.

[illegible] method is described in detail in the author's work:

Fig. 4.

[illegible] 1907," pp. [illegible]. Consequently I need here only give the following hints.

Fig. 5.

To begin with, the instrument is adjusted on perfectly smooth ground, as above described. After the one field to be explored has been divided into squares, with sides 10 meters long at the

most, observations are made with the inclinator in each corner of every square in the following manner:—

The compass is placed horizontally and is turned on the horizontal plane till the central line through the axle-pins of the compass is at right angles to the direction of the needle, or, in other words, so that the needle is placed at 90°. Then the compass is turned on its axle-pins, so that it has a vertical position. In this position the needle is only affected by the vertical component of the ore, and this causes a greater or lesser

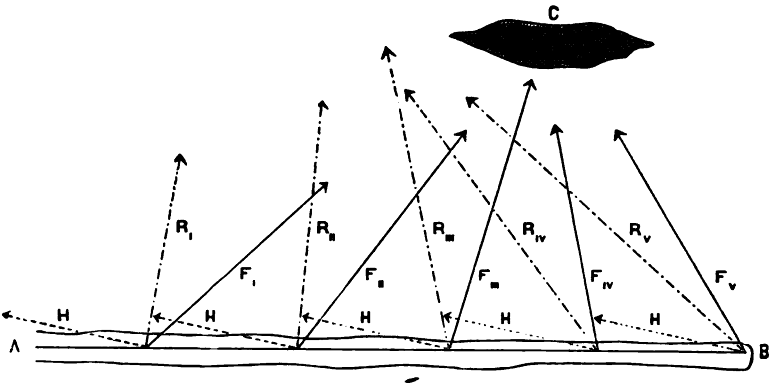

Fig. 6.

inclination of the needle. If the magnetic force of the ore is P, and the angle of the inclination is V, then we have—

$$P = K \tan. V.$$

If we mark the value of V on a map, and the points for which the same V-values were obtained are united, we get a system of curves, isoclinic curves, which are more or less regularly grouped around a certain centre whose V-value is greater than that of all the others (see Fig. 6). Immediately under this centre, where $V = V$ max., the greatest mass of ore always occurs.

Besides for surveys at the surface, both the magnetometer and the inclinator are also used for surveys underground, in galleries and in other places, for exploring the ore. For this purpose the sine method is generally used. If H (Fig. 6)

suggestions, made complete magnetic measurements and maps of the Iberian Iron Ore Co.'s mines near Pedroso (Spain). These were the first complete magnetic measurements which have been made of iron ore fields in Europe outside of Sweden, except, perhaps, some few in Finland. By means of these measurements, which were made both according to Thalén's and Tiberg's methods, much has been learnt in regard to the site, &c., of these mines, and they have, on the whole, been of the same use at Pedroso on 38° latitude as in Sweden on 60° latitude.

The benefit of magnetic measurements in ore fields has also been proved in the United States, and there is no doubt that such measurements would be of great use in all countries which have been above mentioned as possessing magnetic iron ores. It is astonishing that people in these countries have not already learned to appreciate the great advantages which are offered to the practical miner by the use of the magnetic instruments described above.

IV. Prospecting for Iron Ore Deposits by Means of Diamond Drilling.

In Sweden, as in several other countries, diamond drilling is used, as well as shafts and drifts, for exploring ore deposits. In other countries larger and more complicated machines are generally used, with which cores from 230 to nearly 400 millimetres in diameter are obtained, and which can drill holes as deep as 2000 metres.

Such large diamond drills have only on a few occasions been used in Sweden, and on account of the great compactness which, as a rule, characterises both our ores and their country, it is not at all necessary to use drilling machines which give cores of so great a diameter. In our iron ore mines we have, since 1887, used very simple, cheap, and easily transportable diamond drills which bore holes whose cores have a diameter less than one-tenth as great as the smallest diameter given above.

All the drilling done with these machines has been executed by the Swedish Diamond Drill Rock Boring Co., Ltd., in Stockholm; and the total depth of the borings put down by this

nitro-glycerine have been used for an equally long time. Gunpowder is no longer used in mining. Everywhere in the Swedish mines the boring tools are adapted so as to give the greatest possible effect. In order to do this, it is necessary to have the hammer as heavy as possible in relation to the drill, or, if P is the weight of the hammer, and P_0 that of the drill, it should be so arranged that the relation $\frac{P}{P+P_0}$, which also represents the relation between the effective work and the total work, is as great as possible, and has also always been the rule. In single-handed drilling, which is now exclusively used, the weight of the hammer generally varies between 3·5 and 4·5 kilogrammes, and the average weight of the drill 1·4 to 1·7 kilogrammes. Thus, the ratio $\frac{P}{P+P_0}$ is, in Sweden, equal to 0·67 up to 0·75, while in several other countries, where in many places the weight of the single-handed hammer is only 1·25 to 1·5 kilogrammes, the ratio is only 0·47 to 0·50, or at the most 0·57.

Besides adapting this ratio of weight, the working effect has also been raised by using steel of suitable hardness for the drilling tools and by giving the bit a shape suited to the rocks, which are, as a rule, hard.

By these means such advance has been made that it has been possible to use hammers for drilling 1500 up to 3000 metres without their wear or loss in weight amounting to more than 0·3 to 0·6 kilogrammes; and as to the drilling effect, it is usual in underhand drilling to drill 250 to 375 mm. per man per hour, and sometimes up to 600 mm.

Considering the great hardness of the rock and the ore, great efficiency is attained in hand-drilling, and for this reason, rock drilling machines have not come into practical use in the mines until about twenty years ago, since which time their construction has been greatly improved. Their use is, even now, far from common. Another circumstance which contributes to the slight use of drilling machines is that they are not quite suitable for stoping, which is the most common method of working in the mines. There are certain difficulties in placing rock drilling machines on the wide and precipitous stopes, 10 to 18 metres high. On the other hand, in mines where filling is used these machines are much in use, and give advantageous results. Such

has even been introduced in some mines where the ore and rock are compact, but where the ore deposit has been very thick, and mining has therefore been accompanied by difficulties, especially at greater depths. Among the methods belonging to this class, overhand and cross-working are exclusively used, and their adaptation does not, on the whole, differ from the corresponding methods in use in other countries. The only more notable difference is the width of the stope when overhand-working is used in mines with ores of a compact nature. In such cases the width of the stopes can rise to 12 or 15 metres, and sometimes, *i.e.* at Dannemora, up to 30 metres.

VI. Ventilation of Mines.

According to observations which I have made in several Swedish mines, both iron ore and other mines, the temperature does not increase so rapidly towards the greater depths as has been noticed in some other countries. Starting from the level (30 metres) at which the temperature is constant the year round, the temperature in the mines only rises 1° Centigrade for every 50 metres.

In the deepest iron mines the temperature rises up to 10° or 10·3° above zero Centigrade, and it generally varies between 6° or 8° or 9° above zero Centigrade, while the average temperature at the surface in our mining districts is, excepting the very northernmost, between 3·7° and 5° above zero Centigrade. Consequently there is, as a rule, a splendid natural ventilation in all our iron mines. In winter this ventilation is frequently so violent that it is necessary to decrease its intensity in order to avoid the formation of ice in the working chambers. Ventilation brought about mechanically has only proved necessary in very long galleries, or, in general, in working chambers which have long and narrow communications, and in mines of little depth, in which the ventilation is obviously very slow during part of the summer, in July and August, when the temperature at the surface, even at night-time, is comparatively high, but no very expensive or complicated ventilating machines are ever required.

VIII. Surveying Methods—Maps and Models of Mines.

In surveying mines, the "Svenska Markscheidermethoden" (the Swedish surveying method) is almost exclusively used. The surveying instrument used in this method consists of a sighting-tube attached to an alhidade-rule (*ab*, Fig. 7), provided with a tube (*c*) and a vertical graduated circle (*d*), both fastened to one and the same horizontal axle, in such a manner that the tube can move in the vertical plane which passes through one edge of the alhidade (*ab*).

Fig. 7.

This sighting-tube, in surveying, is placed on a plane table fixed to a tripod frame, which at the top consists of a round brass ring (*a*, Fig. 8), whose upper edge is plane turned and polished, and which is at the bottom furnished with a levelling contrivance. In the interior of the ring is fitted a round wooden disc (*b*), supported by the screws (*c*), and adjusted by the screws (*d*) in such a manner that, when drawing-paper of somewhat smaller dimensions than the wooden disc is glued fast on the upper surface of the disc, the disc surface thus covered is close under the upper edge of the brass ring.

...surveying, at least two plane tables are always used. From ...stations the immediately preceding and immediately following ...are sighted, as well as all the fixed points situated between ...stations and the contour-points in the excavation which is ...surveyed.

...surveying station-points and fixed points, the lines of sight ...marked on the paper on which the distances and the angle of ...to the horizontal plane are noted. The contour-points ...marked, with the help of a scale, direct on the paper, after

FIG. 9.

...distances to these from the station has been ascertained. The ...of the mine is then made by combining all these different ...

This method of surveying, which is neither known nor used ...any other country, has been in use for more than 150 ...years. During the last thirty years many improvements have ...made in these instruments, and since steel tape-measures ...come into use in all more important Surveys, very excellent ...results have been reached by this method. The apparatus is

also much more convenient than to use a theodolite, es in excavations of the form which is common in our mines.

If, however, the ore fields to be surveyed are of ver extent, this method is not very suitable to use alone, and cases recourse is had to theodolite surveying. By the help instrument a sufficient number of fixed points are deter and then the remaining work is done by the "Svenska scheidermethoden."

According to the regulations of the Swedish Mining A plans and sections of ore mines must be drawn on a sc 1:800, and must be made in conformity with a Normal drawn up by the Mining Department ("Bergsöfverstyrels Consequently all shafts and other excavations must be on the plans. Further, both the parts of the excavation ore of different kinds occur and that occupied by the co gangues, dykes, &c., must be distinctly marked with ce specified colours. Contrary to the rule in other countri is decreed that no more than one horizontal section ma drawn on each sheet, and this rule has been followed in Sw ever since mine plans first began to be drawn up, 270 years or in 1628.

The mine plans made in this way give a very clear and idea, not only of the configuration of the excavation, but al the mode of occurrence of the ores contained in the mine, for that matter, everything pertaining to the geological c tions of the mine.

According to the Mining Act, it is also decreed that all plans must be drawn in duplicate. One of these copies be kept at the mine, and the other is to be forwarded to Office of Mine Maps belonging to the Board of Trade at S holm, where there is thus a complete collection of all the plans in the country—a collection which is quite uniqu other country having anything similar. It is also presc that in all mines which are being worked every new pie work must be surveyed, at the latest, on the year aft is begun, and it is the mine-owner's duty to forward these plementary surveys to the Office of Mining-Maps, whereby collection of plans at this office are completely revised from to year, and made exactly like those preserved at the mines

[redacted]

[redacted]

The principal increase of the production of iron ore in Sweden began in the beginning of this decade or in 1892, and the further increase of the production to the present amount of somewhat over 2,000,000 tons, is to be chiefly ascribed to the extensive mining operations at the large ore fields of Gellivare and Grängesberg.

In 1897 there was mined (Table IV.)—

In Gellivare, . .	623,110	tons of iron ore.
,, Grängesberg, .	652,977	,,
Total, . .	1,276,087	tons of iron ore.

And thus it is seen that these two ore fields alone produced 61·17 per cent. of the total production of iron ore in Sweden.

Next in order with respect to the amount of ore produced during the year 1897 come the Norberg mines, with a production of 137,897 tons of ore. At the two ore fields Dannemora and Striberg, the production of ore has been about 46,890 and 35,977 tons respectively, and at four mines, Persberg, Stripa, Sköttgrufvan, and Dalkarlsberg, between 25,000 and 32,000 tons. In all other mines, the production of ore has been less than 20,000 tons.

In regard to the production of iron ore in Sweden, both in ancient and modern times, it is worthy of notice that it has never been so great that it could be regarded as too large in relation to the resources of ore on which it was based. Nothing of this kind has happened even when the prices of ore have been high, but the mining of iron ore has always been rather moderate, and can still be said to be so. It is, for that matter, easy to convince oneself of this by making an estimate of the annual average depth of working caused by each year's production of ore, and which is made as implied on page 42. Another proof that the mining of ore has been carried on with moderation is that the majority of our iron mines have not reached any considerable depth, notwithstanding that many of them, some of which contain the most valuable ore, have been mined for 300 to 500 years and more. Only two of these mines, Taberg (in Vermland) and Dalkarlsberg (in Nerike), have

TABLE II.—*Analyses of Swedish Iron Ores.*

Name of Mines.	Fe_2O_3.	Fe_3O_4.	FeO.	MnO.	MgO.	CaO.	Al_2O_3.	SiO_2.	P_2O_5.	S.	Cu, Co, TiO_2, &c.	Loss on Ignition.	Total.	Fe.	P.
Bispberg	2·30	95·41	...	0·35	0·79	1·40	0·11	0·40	0·010	0·006	Cu trace	.	100·776	70·7	0·0045
Brunna:															
No. 1	...	82·83	2·27	0·27	2·96	0·90	2·62	7·10	0·032	0·018	Cu 0·002	...	99·002	61·75	0·014
No. 2	...	71·90	3·07	0·28	4·47	2·50	2·91	13·30	0·041	0·025	Cu 0·002	0·35	98·848	54·45	0·018
Burängsberg	...	62·68	9·81	3·53	3·46	4·20	0·36	7·30	0·009	0·066	..	8·80	100·215	53·02	0·004
Dalkarlsberg	51·04	28·95	...	trace	4·45	2·61	0·60	12·29	0·137	trace	...	..	100·077	56·72	0·06
Dannemora ore field:															
"Norra fältet" (N. part)	...	65·86	1·43	0·89	4·34	7·62	1·08	15·32	0·002	0·171	...	2·80	99·513	48·80	0·001
"Mellanfältet (mid. part)	...	71·65	0·71	2·23	5·66	5·20	1·49	9·30	0·005	0·027	..	3·00	99·272	52·44	0·002
"Sodra faltet" (S. part)	...	72·25	1·50	2·05	4·14	5·50	2·60	8·90	0·007	0·038	...	1·80	98·785	53·40	0·003
Fagerberg	...	69·12	...	2·11	1·84	9·86	2·60	13·60	0·023	0·33	Cu 0·12	...	99·603	50·04	0·010
Finnmossen:															
"Bruten"	...	79·64	...	0·29	3·78	3·30	4·31	8·55	0·023	...	...	...	99·87	57·66	0·010
"Plock"	...	66·53	...	0·32	6·29	5·78	4·50	16·10	0·016	...	...	...	99·52	48·17	0·007
"Finvask"	...	77·01	...	0·29	4·41	3·56	4·44	9·90	0·014	...	...	..	99·61	55·76	0·006
Fogdhyttan	...	76·92	...	...	trace	0·34	...	23·13	0·011	traco	. .	...	100·421	55·63	0·005
Gellivara, ore A	...	...	...	...	...	...	...	...	...	...	...	...	..	67·0 to 70·0	0·01 to 0·05
" " B	...	...	...	...	...	...	...	...	...	...	...	...	...	66·0 to 69·0	0·05 to 0·10
" " C	...	...	...	...	...	...	...	...	...	...	...	. .	...	65·0 to 67·0	0·10 to 0·80
" " D	...	...	...	..	...	...	...	...	...	...	...	...	...	63·0 to 65·0	0·70 to 1·50
" " E	...	...	...	...	...	...	...	...	...	...	...	..	...	57·0 to 61·0	1·50 to 3·0

TABLE II.—*Analyses of Swedish Iron Ores*—(*Continued*).

Name of Mines.	Fe_2O_3.	Fe_3O_4.	FeO.	MnO.	MgO.	CaO.	Al_2O_3.	SiO_2.	P_2O_5.	S.	Cu, Co, TiO_2, &c.	Loss on Ignition.	Total.	Fe.	P.
Norberg:															
Stortägtgrufvan	35·79	29·00	...	0·61	0·65	1·90	0·91	31·54	0·011	0·014	Cu 0·003	...	100·428	46·05	0·005
Flinthedsgrufvan	...	65·05	6·81	4·17	6·00	3·60	1·44	9·50	0·016	0·039	...	3·20	99·825	52·40	0·007
Kallmora- and Norrgrufvorna	...	81·3 to 85·8	0·1 to 1·0	0·1 to 0·14	3·6 to 3·7	1·3 to 2·07	1·4 to 2·2	6·9 to 10·85	0·013 to 0·018	0·008 to 0·028	Cu trace	...	100·263	59·05 to 62·90	0·006 to 0·008
Långgrufvan	17·61	45·33	...	0·23	6·52	5·54	0·98	23·70	0·013	0·011	Cu trace	...	100·134	45·30	0·006
Riddargärdsgrufvan	65·43	5·30	...	0·28	0·65	1·86	0·41	26·04	0·050	0·009	Cu trace	0·20	100·229	50·00	0·022
Risbergsfältet	31·41	36·54	...	0·27	0·51	3·90	0·99	26·30	0·064	0·014	Cu 0·003	...	99·991	48·45	0·028
Bondgrufvan	44·19	23·78	...	0·19	0·65	4·10	1·15	25·84	0·048	0·019	Cu trace	...	99·967	48·15	0·021
	72·75	7·05	...	7·38	1·15	1·20	1·58	3·90	0·057	0·019	Cu trace	6·0	101·086	56·00	0·0025
Klackbergsfältet	...	58·00 to 78·80	0·8 to 7·8	3·98 to 6·8	3·8 to 5·8	2·9 to 3·6	0·5 to 1·3	1·4 to 3·5	0·057 to 0·009	0·017 to 0·096	Cu 0·015 to Cu 0·020	4·6 to 15·9	99·207	48·1 to 57·7	0·0025 to 0·004
	...	43·9 to 50·7	7·1 to 7·6	5·4 to 5·9	6·4 to 7·6	7·2 to 9·3	2·7 to 2·8	2·4 to 3·2	0·008 to 0·009	0·018 to 0·065	Cu 0·004 to Cu 0·025	17·4 to 21·8	100·765	37·3 to 42·6	0·0035 to 0·004
Kolningbergsfältet	...	58·87	6·39	6·67	5·19	3·60	2·20	5·10	0·007	0·052	Cu 0·015	12·30	100·294	47·60	0·003
Johannisbergsgrufvan	...	62·77	7·26	6·50	5·00	1·90	1·88	0·70	0·006	0·040	Cu 0·005	14·00	100·141	51·10	0·0025
Nordmark:															
Nygrufvan	...	68·58	...	0·60	5·50	6·27	1·95	16·90	0·023	...	...	...	99·80	49·61	0·010
Kogrufvan	...	68·58	...	0·50	5·75	6·41	...	16·00	0·016	...	...	1·65	98·89	49·66	0·007
Nyberg	...	64·32	...	0·23	trace	1·07	10·11	24·33	0·150	0·05	...	...	100·26	46·58	0·066
Nyäng:															
Nya Östergrufvan	...	79·40	...	0·11	2·68	4·94	1·29	10·22	...	...	...	...	98·64	57·00	...
Noregrufvan	...	71·25	0·49	0·10	4·98	5·60	0·56	15·40	0·006	0·030	...	1·20	99·625	51·98	0·003
Persberg:															
Skärstöten	50·13	...	23·55	0·34	7·86	5·46	2·03	8·10	0·025	0·014	...	3·38	100·889	53·48	0·011
Gustaf Adolfsgrufvan	50·92	...	23·00	0·31	5·66	5·87	0·65	9·22	0·030	0·015	...	3·68	99·355	53·54	0·013
Alabamagrufvan	48·88	...	24·68	0·24	6·56	1·15	0·87	15·38	0·023	0·012	Cu trace	1·72	99·515	53·41	0·010
Krakbogrufvan	48·08	...	23·52	0·33	3·13	9·42	1·17	15·00	0·004	0·020	Cu trace	...	100·674	51·95	0·002
Hällgrufvan	46·79	...	24·40	0·27	5·28	6·26	1·87	15·47	0·020	0·015	Cu trace	...	100·375	51·73	0·008

TABLE II.—*Analyses of Swedish Iron Ores*—(*Continued*).

Name of Mines.	Fe_2O_3.	Fe_3O_4.	FeO.	MnO.	MgO.	CaO.	Al_2O_3.	SiO_2.	P_2O_5.	S.	Cu, Co, TiO_2, &c.	Loss on Ignition.	Total.	Fe.	P.
Striberg:															
Fallgrufvan "Blodsten"	45·30	27·62	...	0·13	0·18	0·50	0·30	26·00	0·030	0·014	...	...	100·074	51·71	0·013
Fallgrufvan "Svartmalm"	9·80	61·94	...	0·19	0·12	0·50	0·35	27·25	0·016	0·014	...	...	100·180	51·71	0·007
Komministergrufvan	60·60	12·42	...	0·22	0·18	1·80	0·29	24·55	0·005	0·014	..	...	100·079	51·44	0·002
Komministergrufvan	17·02	77·84	...	0·28	0·56	0·60	0·54	3·10	0·021	0·012	...	...	99·973	68·27	0·009
Mossabergsgrufvan	60·90	10·05	...	0·23	0·63	1·20	0·47	26·60	0·041	0·019	...	...	100·140	49·90	0·018
Stripa	25·09	47·56	...	0·31	2·21	3·10	0·43	21·70	0·019	0·002	...	0·20	100·60	52·00	0·008
Stråssa	26·16	37·41	...	0·37	1·62	1·30	2·20	30·60	0·017	0·034	Cu 0·015	...	99·726	45·40	0·007
Ställberg	...	64·22	6·17	7·43	3·08	2·64	2·17	8·00	0·021	0·044	Cu 0·012	6·00	99·787	51·30	0·009
Svartberg	...	56·90	...	18·42	1·64	2·34	3·06	9·26	0·024	1·34	Zn 0·44 Pb 0·25	7·13	100·804	41·20	0·011
Svartvik	44·03	...	23·55	2·55	4·40	7·74	1·64	7·78	0·013	0·011	...	8·95	100·664	49·14	0·006
Taberg (Småland)	...	43·45	...	0·40	18·30	1·65	5·55	21·25	0·127	0·013	Cu 0·02 TiO_2 6·30	H_2O bitumen 2·60	99·660	31·45	0·056
Taberg (Vermland)	...	74·84	...	0·14	6·08	4·04	0·40	14·40	0·019	...	...	...	99·90	54·36	0·008
Timansberg:															
1 A	1·35	86·38	...	0·10	1·92	1·44	1·36	7·10	0·016	0·014	Cu trace	...	99·680	63·60	0·007
1 B	1·67	75·82	...	0·10	4·14	1·60	1·44	14·10	0·018	0·041	Cu 0·005	...	98·934	56·20	0·008
Vigelsbo	...	74·49	0·84	0·37	4·18	4·30	2·30	12·50	0·016	0·055	...	0·20	99·251	54·59	0·007
Vikersgrufvan	...	57·34	...	3·66	9·20	2·34	2·16	10·83	0·05	0·24	...	13·20	99·02	41·50	0·022
Vintjärn	48·17	...	15·74	0·15	10·77	2·77	2·20	19·93	...	...	...	...	99·730	46·00	...
Ånnenäs	...	72·01	0·72	0·08	1·33	5·40	1·60	15·56	0·037	0·025	Cu trace	2·20	98·962	52·70	0·016
Ånggrufvan	...	75·84	...	0·57	5·48	3·25	1·45	11·40	0·030	0·03	Co 0·012 Zn trace	1·15	99·212	54·90	0·013
Östanberg	...	64·15	...	...	2·65	5·05	2·65	25·40	0·022	0·058	...	...	90·980	46·50	0·010

TABLE IV.—*Number of Mines in Work and Yearly Average Production of Iron Ores* 1861–95 *and* 1891–97.

Years.	Number of Mines in Work.	Yearly Average Production of Iron Ores, 1861–95 and 1891–97. Metric Tons.
1861-1865	500	453,486
1866-1870	422	542,323
1871-1875	576	784,707
1876-1880	382	721,232
1881-1885	496	874,423
1886-1890	530	930,037
1891-1895	339	1,517,434
1891	346	985,255
1892	353	1,291,933
1893	341	1,481,487
1894	326	1,926,523
1895	327	1,901,971
1896	338	2,038,094
1897	...	2,086,119

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1876–1880	382	721,232
1881–1885	496	874,423
1886–1890	530	930,037
1891–1895	339	1,517,434
1891	346	985,255
1892	353	1,291,933
1893	341	1,481,487
1894	326	1,926,523
1895	327	1,901,971
1896	338	2,038,094
1897	...	2,086,119

THE DANGER OF USING TOO HARD STEEL RAILS.

By C. P. SANDBERG, M.Inst.C.E.

Having had many years' experience as consulting engineer and rail inspector for the Swedish State Railways, as well as for most of the private lines in Sweden, I propose to give a short outline of this experience with special reference to the danger of using too hard steel rails.

Duration of Iron Rails in Sweden.

The *iron rails* used up to 1872 were mostly made in Wales, but, owing to their unsoundness, were then superseded by steel rails. The superiority of steel rails was demonstrated after five evenings' discussion at the Institution of Civil Engineers in 1868, when I read my first paper on "The Manufacture and Wear of Rails."

However, as a proof that good iron rails could also be made, the experience in Sweden may be mentioned, where the rails on the State lines have had an average life of twenty years, and a total tonnage passing over them of ten million tons; also that of the largest private railway in Sweden, the Bergslagarnes, 300 miles long, all the rails for which were made at the Dowlais Iron-works. They have had an average life of twenty years, and ten million tons of traffic have passed over them, and during the whole time only half-a-dozen rails have broken. The President, Mr. E. P. Martin, who was then works manager at the Dowlais Works, should have the credit of these good results of his rails.

Steel Rail Fractures.

As regards the duration of *steel rails*, Sweden has not as yet had enough of experience, as none have worn out; but as regards

to 1 per cent., the silicon being up to 0·1 per cent., and the phosphorus not more than 0·075 per cent.

Danger of using too Hard Steel Rails.

There have been some sensational articles published of late years, principally in America, arguing in favour of rails with both 0·50 per cent. and 0·60 per cent. carbon and even more, and this I would strongly contest, particularly in countries with a cold climate like Sweden, on the following grounds:—(1) That so hard a rail, subject as it is to so many variations in the manufacture, will unavoidably bring in an element of danger to rail fractures in such a way as to make the rail fly in many pieces, and thus without doubt cause accidents; (2) that the flattening of rail ends can be partially overcome by giving greater bearing surfaces between rails and fish-plates, as in my new rail sections and rail joints, as well as by avoiding too heavy wheel loads and also by adopting heavier rails. (3) As for wear, it is doubtful whether hard rails stand most wear; at least Mr. C. B. Dudley, chemist to the Pennsylvania Railroad, argues in favour of soft rails, and Mr. P. H. Dudley of the New York Central advocates hard ones, even containing 0·60 to 0·70 per cent. of carbon and more.

In any case, no railway engineer has a right to run any risk to the safety of his line by using too hard rails that may fly in many pieces, causing accidents, for this would be the most expensive for the railway, leaving out the question of humanity, even should the flattening of rail ends not be altogether preventable with a medium hard rail steel.

Experiments having been made with a few casts on this excessive hardness of carbon, *i.e.* 0·60 per cent. in 80-lb. rails, it was found that they flew in many pieces with less than half of the specified tup test for safety (Plate IV.), while those with 0·45 per cent. carbon stood one ton falling 20 feet. To make 0·60 per cent. carbon rails to stand the tup test, every other element must be brought down to a minimum, and after all it would be no gain to either producer or consumer, as hardness is much better obtained by carbon together with manganese, and even silicon. Besides, it must be remembered that manufacturers are not

use heavier rails, of a safe degree of hardness, and thus economi in both sleepers and cost of maintenance, and not be led astra by sensational articles in trying to run up to extreme hardnes to make up for the deficiency in the present too light weigl of rail section, thereby risking accidents.

I have at least followed a safe practice for both the Swedisl State and private lines, and also for other parts of the world, witl such results that I have not yet had any rails flying in many pieces or causing derailments, and the economical wearing results have also been very satisfactory.

Although I am quite open to conviction and ready to move with the times, I have thought this opportunity of the Iron and Steel Institute's meeting in my native land too precious to let it pass without having the benefit of a discussion and the results of your valuable experience on this question, which is most important for Sweden as well as for other countries.

As I take it that the object of the Institute's visits to foreign countries should be to exchange information, Sweden, I think, is able to offer in exchange for the above information demanded on the danger of using too hard steel rails, some very interesting facts on light railways—all the more valuable since such have now been allowed to be introduced in England, where more than one thousand miles are now authorised to be built, and the first has just been started.

Light Railways in Sweden.

With the building of these light railways in Sweden I have been connected, as far as the rails are concerned, since the commencement, and I have, during these thirty years, constantly published in the English press—principally in *Engineering*—what has been going on in Sweden, and it is only its great distance from England that can explain why so little good has resulted from these representations; but now that you are here, although not specially railway engineers, I would strongly recommend you to study the light railways of Sweden, not only from the map accompanying this paper, but also in reality. There is nothing that Sweden has to be so proud of as the development in the last forty years of its railway system. The State laid out

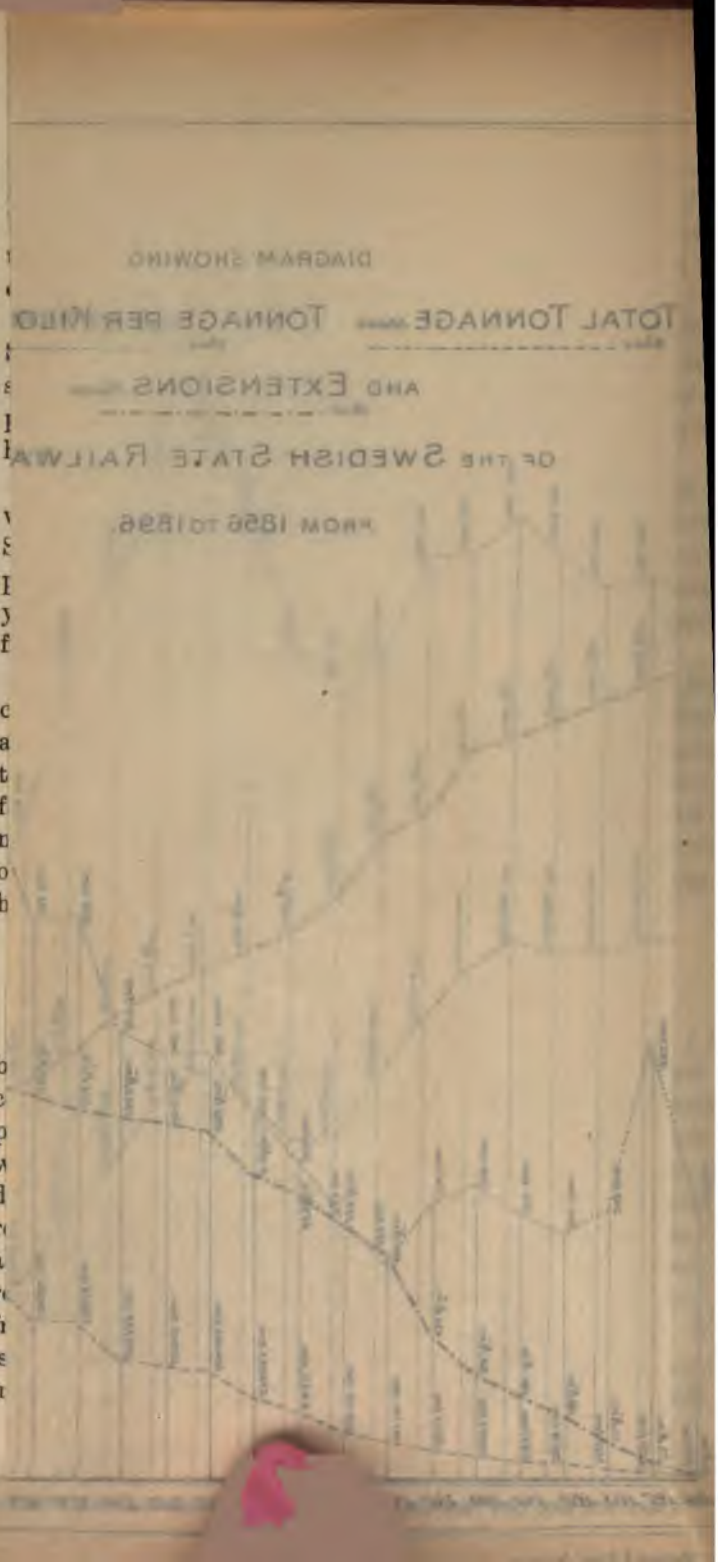

PLATE IV.

port for the new mineral line to be built from Gellivare to Ofoten, and it is to be hoped that the private railways will follow the example of increasing their rail weights generally in proportion to their requirements, in order to save maintenance and obtain cheaper transport.

CONCLUSION.

From the facts brought forward in this paper it follows that we, in Sweden, with our severe climate, should certainly not try to remedy the deficiency in weight of rails used at the original construction of our railways by now resorting to a dangerous hardness of rail steel retaining the same section, but rather adopt a heavier weight of rail of moderate hardness, and consider safety before all.

inability to meet them in Sweden, along with my best wishes for a happy and prosperous visit."

Dr. ÅKERMAN said, as he still kept to the position he officially had taken already in 1884, that the tup test was the most important for rails, they could easily see that he so far agreed with Mr. Sandberg; and he thought that if only the tup test was used in a proper way there was no danger in making the rails as hard as the proof would admit. As far as he could see, the hardness would then just answer to what Mr. Sandberg was now advocating.

Mr. ROBERT W. HUNT (Chicago) said, the President having known him so long and so well, he could appreciate with what great hesitation he ventured to address the Institute, and particularly upon any subject connected with steel rails, or, in fact, any product of the Bessemer converter. If he should have hesitated to have done this in England, how much more should he do so in Sweden—the country in which the Bessemer process was first made practical, where the name of Bessemer, however much, and it was ever highly honoured, always recalled the name of Göransson. In relation to what might have been designated as the higher grades of Bessemer steel, they had all of them, and always, speaking for the metallurgists of America, felt that they must sit as pupils at the feet of the Swedish masters, and he thought he might venture to make the statement for their English friends. Of course, he did not refer in any way to the Swedish Bessemer steel ingots or billets which had crossed the water, and later, in some mysterious way, had become the highest grade of Sheffield crucible tool steel; but he did mean that, thanks to pure ores, pure fuel, patient industry, and great intelligence, the Swedish metallurgists had gone far beyond any of them in the results obtained from the Bessemer process.

When it came to the question of quantity and cheapness of production, they of America, disregarding or rising above their well-known national modesty, must claim some recognition. It was with hesitancy that he ventured to discuss his esteemed friend Mr. Sandberg's paper. He did not presume to do so, so far as it applied to rails for use on Swedish railroads. With

territory as possible at the least expense. There too the first rails were of iron—in fact, no others were known. The rolling stock was light, and the speed, judged by modern ideas, very moderate. Even under such conditions the constantly increasing demands of traffic brought unprofitable failure of the best of iron rails. The Bessemer invention came as the saviour of the situation. How often had history repeated itself on this line. As the forests of England failed, mineral fuel was discovered. As the end of that could be calculated or predicted, not only in that, but other countries, once more water power promised to play its part in supplying power by electricity, and thus conserving fuel. At all events, it would seem that without such an invention as the Bessemer steel rail the material progress of the last thirty-five years would have been impossible.

They all knew that the primary superiority of the steel over the iron rail was from its homogeneity; that abrasion, rather than disruption, caused end of service. Now, they also knew that work, either by hammering or rolling, given to steel at high temperatures did not cause much change in its crystallisation, but that as the temperature decreased so did the effect of the applied work increase. The early steel rails were of light sections, and rolled from comparatively heavy ingots. Those ingots were most carefully heated, all the conditions incident to the treatment of tool steel governing the operation. At a comparatively low temperature the ingots were reduced to blooms, they were allowed to cool, carefully examined for flaws, which if discovered were chipped out; the blooms then heated with care, and rolled by comparatively many passes into rails of light sections, and the resulting rails were of close or fine grain or structure. Now, these practically homogeneous rails replaced the built-up or laminated iron ones, and, of course, the comparative difference in resulting wear was most striking. The more lasting and better track led to the increase of speed, then additional wheel tonnage, &c., &c., until these in their turn demanded a better roadway, and so on until they had reached present conditions. In America, at least, these conditions required heavier rails, and at a price which, if demanded from the "fathers," would have been treated as preposterous and never to be. But the conditions existed and must be met.

might be from 0·30 to 0·50 per cent., the controlling officers of at least the western system, for whom he inspected their rails, desired that their 85-lb. rails should be as near 0·50 per cent. carbon as they could induce the makers to give under the liberal latitude of the specification. He had heard more than one prominent American railway official claim that the theory of soft rails coming from so widely recognised an authority as a prominent officer of the Pennsylvania Railroad Company had cost the railroads of the United States hundreds of thousands of dollars through their undue wear. In fact, he might state most confidently that in the States the C. B. Dudley theory had been rejected for a number of years.

Under what are known as the New York Central Railroad's specifications, and which were prepared by Mr. P. H. Dudley, as stated by Mr. Sandberg, high carbon percentages were given. But in America, owing to the vast area of territory and varying geological conditions, the commercial side of the question could not be absolutely ignored; therefore that which might be in every sense available for the New York Central Railroad would be practically impossible for, say, the Northern Pacific system. In other words, commercial conditions governing the mills east of the Alleghany Mountains did not apply to those west of them.

In a paper presented by him to the American Institute of Mining Engineers in October 1895, he endeavoured to fully discuss this. While advocating harder steel for the heavier sectioned rails, he called attention to the fact that as the western available ores were higher in phosphorus, it was not safe to go as high in carbon and manganese in the rail steel made from them as could be done in the east. Accepting his views, many railway engineers had insisted on his specifications being practically followed. Hence he could say that far over 1,000,000 tons of what might be called hard steel rails had been put down by the western railroads.

It was true that the phosphorus percentages had been controlled, but still that element had been higher than in eastern rolling mill practice.

Now he wished to consider the effect of climate. The Michigan Central Railroad ran from Buffalo, through Canada and the State of Michigan, to Chicago. Their standard rail was 80 lbs. per

respects of at least 50 per cent. When they reflected that during the same time the production of some of the rail mills had been increased from say 25,000 to over 40,000 tons per month, it could be appreciated that the mechanical appliances of the mills must have been improved, and that careful watching of the products had been necessary.

The Louisville and Nashville and the Northern Pacific systems had put down some experimental rails, made by the basic open-hearth process, in which the phosphorus was limited to 0·05 per cent. and the carbon made high, the Northern Pacific rails being up to 0·70 per cent. So far the rails had done well. Indeed, based on this experience, the Louisville and Nashville Company joined in underwriting the securities of an Alabama company to enable them to construct a large basic open-hearth plant with a rail mill attached. He was convinced that in America the time was near at hand when the Bessemer process would have a formidable competitor in basic open-hearth in rail production as well as in other lines.

He wished to trespass on their patience a little longer to call the attention of the Institute to a departure in steel rail matters which promised to play a somewhat important part, at least in America. He referred to the M'Kenna process for renewing steel rails. Their President and Past-President, Mr. E. Windsor Richards, had an opportunity of seeing something of this when they were last in the States. Last year the M'Kenna Company treated some 30,000 tons of rails in their mill at Joliet, Illinois. This year they had started an additional mill at Kansas City, Kansas. So far the treated rails showed very well indeed, and he firmly believed the day would come when the originally purchased section would be determined upon with the view of having the rail renewed at least twice, and perhaps three times—that was, after a 100-lb. rail had given its first service it would be renewed as a 95-lb. one, then as a 90-lb., and then 85 lbs. per yard, and each time the quality of the rail would have been improved.

Mr. E. Windsor Richards, Past-President, said that they all knew Mr. Sandberg's great experience in the inspection of steel rails, and how very careful an engineer he was; and he might

Sandberg whether he considered that sufficient attention was paid to the temperature at which rails were rolled and to their subsequent treatment, more especially as regards the rate at which they were allowed to cool. It was the alteration of the surfaces of the rails which appeared to the Committee to be of very great importance as a determining cause of fracture.

Mr. G. J. SNELUS, Vice-President, said he should like to add his testimony to what had been said by Mr. Sandberg as to the advisability of not putting too much carbon into the steel rail. He had always considered that the medium course was best in these things, and his experience as a chemist and manufacturer of steel rails over a long series of years convinced him that it was far safer and more economical to use a medium hard rail than it was to go for a very high carbon rail or a very low carbon one. He quite agreed with their American friend, Mr. Hunt, that they might have a high carbon in steel, and perhaps ninety-nine rails out of a hundred would be fairly satisfactory; but if they exceeded 0·5 per cent. of carbon, and they had happened to get, say, 0·2 per cent. of silicon, which was quite within the bounds of possibility, they might rely upon it that they would find a very brittle rail. All the tup tests that he had seen had proved that. He had for many years followed the tup test by the chemical examination, and he had invariably found that where a rail broke under the tup test, if the carbon was fairly high, the silicon was high, and really the cause of the fracture. If they could always be sure of keeping the silicon low, they might go for the hard carbon rail. But there came in the difficulty that it was not absolutely possible always to be sure that the silicon did not get too high to add to the hardening effect of the carbon and produce brittleness. Therefore he thought Mr. Sandberg was quite right in advising them to keep within moderate limits in the amount of carbon they put into the steel. Although some advantage might be gained in the wearing power of the harder steel rail, he was quite sure that in the end it was counterbalanced by other drawbacks.

With regard to Sir Lowthian Bell's remark that the fractures of heavy steel rails were as frequent as those of lighter steel

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heavier rails they had not increased to the extent they ought to do, in his opinion, the size of the ingot in proportion to the section of the rail rolled. Some people were using to-day for a 40-lb. rail the same section of ingot that they would roll a 100-lb. or a 120-lb. rail from. He thought that that should be altered.

Mr. Robert W. Hunt (Chicago) said, with reference to the remarks of the President and Mr. Windsor Richards, they must remember that in America they had ingots 22 inches square for their rail practice; and surely they appreciated that if they fractured a bloom rolled from that 22-inch ingot, say nine inches square, they would find that its structure was no closer than the same sized bloom rolled from a 15 square-inch ingot. His experience as a steel-worker was that the working of steel at high temperature changed its structure to but a limited extent, and that a large ingot must be at a very high heat internally, if not externally, when rolled directly to a large sectioned rail. He was satisfied that a bloom at 10, 9, or even 8 inches square, from a large ingot, was no closer grained than the old blooms of 6 inches square made from a 12-inch ingot designed to produce one rail, or even two rails, weighing from 56 lbs. to 60 lbs. per yard.

He wanted to say one thing with regard to silicon. He strongly advocated a comparatively large percentage of silicon in rail steel; but he wanted it added after the original silicon in the metal had been eliminated. The ingot was nothing but a steel casting. Therefore the practice was to add the silicon to prevent blowholes and have a solid ingot. In America, by running direct, and at high speed, they were enabled to use iron very much lower in silicon than was possible in earlier practice. Hence it was easier to eliminate that element. He wanted to add, certainly, from one to two tenths per cent., but he did not want it *left* in, but added in the same way as the recarboniser.

It was quite right that great care should be exercised in the physical treatment of the heavy sectioned rail; in other words, as little work as possible should be given that rail under the cold press; and he was quite surprised that in England they paid so little attention to the hot straightening of their rails.

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to accord with the conclusions of the Board of Trade Committee, they would know probably more and be better satisfied as to the actual conditions under which steel rails should be passed into service than they had hitherto been. But if Mr. Sandberg's conclusions should happen to be opposed to those of the Board of Trade Committee, he was afraid they would not be likely to get any further forward.

Mr. Hunt had referred to the great variations that had occurred in rails manufactured some years ago for American railways. He was reminded by what Mr. Hunt had just said, that Mr. Potter, of the Illinois Steel Company, had described a lot of rails that they had analysed some years ago, where the silicon, phosphorus, and carbon were about equal at 0·17 per cent. Of course, as Mr. Potter remarked at the time, no inspecting engineer would pass such a rail at the present time. These particular rails had been in service for fifteen years, and were sent to the Illinois works for the purpose of being trimmed up, with the view of serving for perhaps other fifteen years. This was a clear proof of the wide range of difference that was possible in steel rail composition without serious danger.

The PRESIDENT said, with regard to the question put by Mr. Jeans as to what the Committee on Steel Rails were doing, he might say that a large amount of material had been collated, but as yet the members of the Committee were not in a position to make the matter public.

Professor J. O. ARNOLD said, as representing Sheffield in a semi-official manner, he rose with considerable diffidence to speak as to the practice alleged by Captain Hunt to prevail in Sheffield as to purchasing Swedish Bessemer and sending it across the Atlantic as crucible cast steel. If such allegation were true, it seemed to him that American buyers were either very foolish or very untechnical, and that the remedy was in their own hands, because they could buy the Bessemer steel direct from Sweden. Experts should have little difficulty in identifying genuine crucible cast steel.

He had read Mr. Sandberg's paper, and he strongly supported his views as to chemical composition—firstly, as one who had

about 0·3 per cent. If they annealed that steel, they destroyed the continuity of those lines and "balled them up" into little nodules, so removing to a large extent the cause of extreme brittleness in steel castings.

Then as to the manganese which had been touched upon in the paper. He believed in the proportion of manganese advocated by Mr. Sandberg for the reason that in all the fairly high manganese steels which he had examined he had never yet found any of that meshwork of sulpho-silicide of iron. With about 1 per cent. of manganese present the sulphur was all "balled up" in small nodules, probably owing to the greater fusibility of the manganese sulphide. That he could only provisionally speak of at present. They were not sure about the exact micrographic details, but as the mechanical effect it undoubtedly existed. In the case of railway material its failure in the one hundred thousandth case was that against which the engineer had to guard. They might get a very large percentage of high carbon rails to stand, but still there was a much greater liability to fracture with them. There was no doubt whatever about it that steel with 0·35 to 0·45 of carbon was far less liable to fracture under the influence of sudden vibratory shocks than a rail containing 0·6 per cent. of carbon. Any one who had made a long series of drop tests would know that.

Professor H. M. Howe considered that certainly we must avoid too great hardness; but what hardness was "too great"? The question before the meeting seemed to him purely one of reasonableness. On one hand, as carbon was lessened the safety of the rail was increased, but its life shortened. Rails with 0·10 per cent. of carbon would certainly be less liable to break than those of 0·35 per cent., exactly as the latter are in turn less liable to break than those with 0·50 per cent. of carbon. If the 0·50 per cent. carbon rail were dismissed simply because it was, though more enduring, less safe than the 0·35 per cent. carbon rail, by parity of reasoning the latter should be rejected, because, though more enduring, it was less safe than the 0·10 per cent. carbon rail—an evidently absurd conclusion. The speaker believed that we have to learn, not by mottoes, however wise, but by experience, and experience alone, how

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suffice. So, too, cast iron was once good enough for rails, then wrought iron, now soft steel. But he did not believe that progress had ended, but that there would be further evolution, and that we should have more enduring rails. What the path of progress would be, of course, no one could predict. The Bessemer converter might be discarded, and the basic open-hearth furnace be used, both because it led to lower phosphorus, and because, as usually worked, it led to better quality even for like composition. Heat treatment might come, not this year nor next, but eventually; for he could see no reason why a wiser management of the heat remaining in the rail as it left the finishing pass need be expensive. With, or perhaps before, other improvements might come greater hardness, if, as might reasonably be supposed, that would give greater endurance; but with greater hardness there would come greater purity, and greater care in manufacture, in making, casting, rolling, and treating. He considered the Swedish lesson that prevented crude methods admitted of great improvement in several directions.

Mr. HARBORD said that, judging from their experience at Cooper's Hill, they found that rails with 0·35 per cent. to 0·45 per cent. of carbon were safer and gave better all-round results than higher carbon rails. There could be no doubt that the lower the carbon the safer the rail, but, as Professor Howe had pointed out, this was simply equivalent to saying that 0·100 per cent. carbon steel was less brittle than 0·50 per cent. carbon steel, and it was necessary to make rails of a material possessing sufficient hardness to resist too rapid wear. What was required was a material combining considerable ductility with hardness; and although opinions differed as to the composition which would give the maximum of hardness with minimum of brittleness, sufficient data had been collected to enable a fairly general agreement to be come to as to what should be considered a dangerous composition for rails. He was somewhat surprised that Mr. Sandberg should advocate the discarding altogether of chemical analysis by engineers, and the relying alone upon the tup test. That the tup test was the right mechanical test for rails there were probably not two opinions; but an insistence on low phosphorus, sulphur, &c., was of equal importance; and both in the interest of the

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meeting the results obtained by an experience of more than thirty years about the wear of rails in Belgium. The following were the test conditions of the State and the Grand Central Railways. First, let them take the State Railways. There they had two sizes, one of 76 lbs., with a tup test of 600 kilogrammes falling from a height of 4 metres; the other a 104-lbs. Goliath, with a test of 1000 kilogrammes falling from a height of 6 metres. The steel for both has a tensile strength of 60 to 70 kilogrammes per square millimetre, with 13 per cent. elongation. With their Bilbao ore this corresponded to a steel of 0·35 per cent. carbon. As to the Grand Central, the rail was a 75-lbs. rail, with a tup test of 500 kilogrammes falling 4 metres; tensile strength, 60 kilogrammes minimum; elongation, 13 per cent. minimum; that was practically the same steel as for the State Railways—viz., 0·35 per cent. carbon.

Then the conditions of wear on the State Railways were as follows: The maximum wear of the rails must not exceed 7 millimetres after five years of heavy traffic. If more than 2 per cent. of the rails were worn 7 millimetres, all the lot under guarantee were subject to a penalty of 50 per cent. of its value to be paid by the maker to the State. His firm, the Société Cockerill, at Seraing, had 8189 Goliath rails carefully inspected after twelve years' guarantee, and the result had been an average wear of $1\frac{1}{3}$ millimetre. There was not a single rail broken in two. Further, on 330,000 rails, or 130,000 tons of Goliath rails, only a few had been taken out during that period on account of the split ends corresponding probably to the tops of the ingots. The first of these twelve years had given the following result—replaced, 0·01 per cent.; and the average during the twelve years did not reach 0·001 per cent. replaced per annum.

Then as to the Grand Central, since 1865 they had employed for wear and renewal of their lines 118,860 tons of iron and steel rails. Amongst these, 90·6 per cent. of iron rails had been replaced; and in this period of thirty-two years only 2·67 of steel rails had been worn out or broken. This showed that the steel rails had a duration thirty times as long as the iron rails. According to his calculations the Grand Central had an average on twenty-five years' experience of not more than 0·003 per cent. worn-out rails per annum. Then taking the figures in Mr.

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carbon, and many eminent authorities had given that as the main reason for the rail breaking into so many pieces.

Dealing with things as they were, it was well known that regularity and perfection could not be obtained, and therefore it was the best policy to guard against accidents by extra strength. In 1890 he read a paper in Sheffield before the Institution of Mechanical Engineers, "Steel Rails considered Chemically and Mechanically," when the question of silicon was discussed. His desire then was to have solid ingots free from blowholes or pipes. He was supported by many of the makers, and he had extensive experiments made with steel containing a large quantity of silicon, and the result was that while it was proved to be excellent for small ingots (one for each rail), the larger ingots of one ton or one and a half tons showed that the shrinkage in cooling of the silicon steel when it came up to a high percentage was so much greater than with carbon hard steel, that the danger of hollow ingots was very much increased.

For Sweden they had had some 6000 tons of rails in which there was 0·2 per cent. of silicon and about a quarter per cent. carbon. These had been made from single ingots, and had been down on the line ten years, showing excellent results from this composition, as not one of them had yet broken and none split from pipy ingots.

Mr. Sandberg, after the meeting, sent the following communication:—

In reply to Sir Lowthian Bell's communication through Sir James Kitson, I am rather astonished to hear his opinion that fractures are generally due to mechanical causes rather than to chemical, as, whenever I investigate the causes of rail fractures, in nine cases out of ten I find that chemical composition is at fault. With regard to a heavy rail breaking as much as the light one, it stands to reason that a crack once present will develop independently of the weight of rail (as Sir William Siemens explained in the discussion on the paper on basic steel read by Sidney Thomas at the Society of Arts), but in the heavier rail the crack develops more slowly, as it is subject to less vibration and deflection.

I may here refer to the plate of rail fractures, and the 0·60 carbon rails which broke into many pieces at half the usual tup

be made up by chemical means or the addition of carbon. This of course is so, and I have always allowed a chemically harder rail for heavy sections than for light ones. He often quotes hard rails without giving the percentage of carbon or the chemical composition.

He seems to acknowledge the hardening effect of cold rolling. In America, the rails leave the rolls at a much higher temperature than they do in England owing to their faster running mills compared with the English, and they must obtain the fine-grained steel more by chemical means than in England. In other words, they must make up for their less physically hard steel by chemical hardness, and arrange the carbon according to the phosphorus present in different parts of their great country.

There is no reason why good rails, both for safety and wear, should not be obtained in both countries; but it is a mistake for one country to try to adopt part of another's practice when the conditions are different. For instance, it would be absurd to try to introduce in England with its greater physical hardness of rails the high carbon found possible in America, or as I have long argued, no standard fixed composition can be given for all countries. It is high time, after these years of discussion, that all this talk about a standard composition were finished, and let us give up the ambition of each country or engineer trying to prove his composition the sole right one.

Regarding the sensational articles which Mr. Hunt stated to be true, I did not mean that they were untrue, but that they caused a sensation in Europe among responsible engineers, who were not metallurgists, and who jumped to the conclusion that the same composition was advisable in Europe for the sake of economy, thereby endangering safety.

The same also applies to congresses and meetings in general where striking facts are first mentioned, but only part of the conditions under which they have been obtained are given. As an example, take the case of Sweden, where there was an intention to imitate the American carbon with the English conditions of manufacture, which I opposed on the ground of safety and suggested that a trial be made first. The result is shown in the plate of rail fractures, and the idea was given up; and as before, the tup was left to decide the maximum amount of carbon to be

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instance, from several slight causes combined, a fracture may occur which will cost more than any saving aimed at. As for his explanation of fracture, when a flaw once exists in a heavy rail, it is quite to the point. As to the President's statement about the low silicon in American pig iron used for rail steel, I think it is a great advantage, and I wish the same could be introduced into England in order to obtain greater regularity of heat in the blow and silicon in the rail.

I agree with Mr. Hunt that starting with a 22-inch square or 15-inch square ingot does not affect the grain of the rail.

I am glad that Professor Arnold, from his micrographic studies, agrees with my theories both as regards carbon and manganese, and we shall look forward with great interest to the promised contribution on high silicon steel.

In answer to Professor Howe's questions what is too hard a rail and what is too high a carbon. Too hard a rail is one that breaks, particularly into many pieces on the road, and engineers must take a surplus of strength for the tup test, and see that regularity is obtained, as only a small proportion can be tested at the tup.

With regard to open-hearth steel replacing Bessemer steel, I think it would ensure greater regularity; but as to open-hearth basic steel, it would, I should think, take a great deal of carbon to get the fine grain desired, and even then regularity would have to be checked closely.

In reply to Mr. Jeans' suggestion regarding light railways, my articles on the subject have been published from time to time in *Engineering*. They are now a little out of date, so I think they may hardly be worth republishing in the *Transactions* of the Institute.

As I have already explained, I do not hold to any empirical composition of steel rails for any country.

My views upon the application of chemistry into rail inspection seem to have been entirely misunderstood by Mr. Harbord, because I wish to discard it in the specifications, except phosphorus. I have for years stated and practised, "Let the chemist guide the engineer and explain the causes of fracture, but not dictate chemical compositions," for with the exception of phosphorus, which I found absolutely necessary to limit low, other

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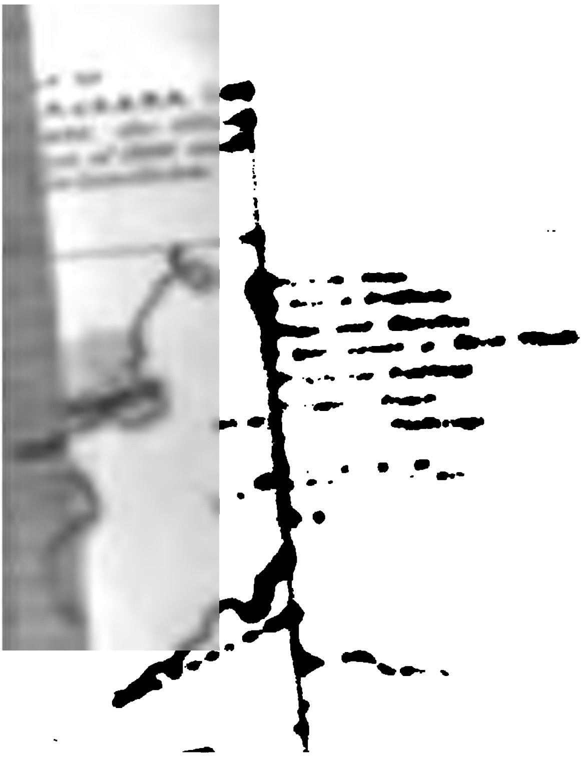
would continue to benefit by Mr. Sandberg's great experience, and begged to propose a hearty vote of thanks to him for his very interesting paper.

Unfortunately, Mr. Greiner's paper on the 200 horse-power blast-furnace gas engine must be taken as read. He regretted this very much, because he thought it was one of the most important subjects at present under consideration of ironmasters. There was another paper on the list, by the eminent geologist Mr. H. Lundbohm, on the remarkable deposits in the Arctic Circle; but as the time was so short and Mr. Lundbohm was unable to be present, it would also be taken as read.

after the railway had been completed from Luleå to Gellivare. In the beginning of the nineties, the present Luossavaara-Kiirunavaara Company, Limited, was formed, but a great part of its property somewhat later was transferred to the Gellivare Malmfält Company, Limited. Another application for a railway concession was made by a Swedish company in 1896, which caused the Government to propose to the Swedish Parliament that funds should be apportioned for surveying the course of a railway, eventually to be taken over by the State, from Gellivare to the Norwegian frontier. And this year an act was passed by Parliament that such a railway shall be built during the next five years. Within a short period the riches embedded in Kiirunavaara and Luossavaara will thus be attainable, and become a blessing both to those now living and to many generations to come.

An exhaustive investigation of the iron ore resources of these mountains was first carried out in 1875, when a great many iron ore deposits in the province of Norrbotten were mapped out, and examined at public expense by the Swedish Geological Survey. In the year 1889, at the expense of a private claimant, a fairly exact map of the mining fields, on a scale of 1 : 1600, was constructed by Mr. S. R. Wibel, and during the years 1890, 1896, and 1897, the author of this paper had occasion to carry out extensive investigations.

Kiirunavaara and Luossavaara are situated 2° 10′ east of Stockholm, at about 67° 50′ north lat., almost exactly halfway between the valleys of the two rivers, the Kalixelf and the Torneelf. The distances from the mountains along the recently projected railway lines are: to Gellivare station 105 kilometres, to Luleå 309 kilometres, to the Norwegian frontier 132 kilometres, and to Victoria Harbour on the Ofoten-Fjord, 173 kilometres. The Kiirunavaara mountain consists of a steep ridge extending for about 2½ miles in length, and is divided into a series of peaks, the highest of which, named the "Statsrådet," attains a height of 748·9 metres above the sea-level, or 248·7 metres above the lake (Luossajärvi) that lies between the two mountains. The other summits, the names of which are given on the accompanying map, Plate V., vary in height from 82 to 239 metres above the lake. The gently sloping, conically



of the mountain is as a rule very steep, sometimes so much so that it can only with difficulty be ascended; the west side has a gentle slope, and the ore rises only very little above the porphyry of the foot-wall.

Attempts have been made to ascertain the width of the ore at the surface by means of magnetic survey and by excavation, as the ore boundaries are exposed by nature only at a very few places. Sometimes, however, the boundaries are fairly clearly indicated by the state of the ground, as the ore has been better able than the porphyry to withstand the effect of erosion, and has thus formed elevated portions, which sometimes rise rather steeply above the surrounding porphyry, that is more gently sloping and covered with gravel. In certain parts of the mining field, especially in the hill "Jägmästaren" and on the low ground north of the "Vaktmästaren," there have been few opportunities of examining the extension of the ore.

The width of the ore in the mountain ridge, as measured, only in exceptional cases falls below 100 metres; it amounts not unfrequently to 150 metres or upwards, whilst in one place, in the hill "Geologen," it is as much as 255 metres. Since the dip of the ore body is found to be rather small, and since the action of erosion in some parts of the district has been to make the outcrop of the hanging-wall much lower than that of the foot-wall, it is obvious that the actual width of the ore, or the horizontal distance between hanging-wall and foot-wall, is in general somewhat less than that above given—a circumstance to which due attention has been paid in the calculation of the ore area. Formerly the dip of the ore body was assumed to be 70° to 80° eastwards from the horizon. During last summer diamond borings were carried out, which, however, have proved that the dip is considerably less.

These borings were put down at three different places, namely, at the "Vaktmästaren," the "Statsrådet," and the "Professorn," and their execution caused much loss of time and great expense, owing to the unusual hardness of both the ore itself and of the porphyry in which it is embedded, the difficulty in transporting machines and boring-tubes to the place, in procuring water, &c.

At the "Vaktmästaren" a hole was sunk at an angle of 55°

the angles of dip found by the diamond borings, varies between 34 and 152 metres, and the average thickness of the ore ridge has been estimated at about 70 metres.

The total ore area in Kiirunavaara, whereby is meant the superficial extent of a horizontal section of the ore body, has been estimated at about 376,000 square metres, of which some 230,000 square metres are uncovered or scarcely covered at all, while in the remainder of the district the ore is known chiefly from the results of magnetic surveying and from a few scattered excavations.

A trustworthy calculation of the whole quantity of ore could not be made with the material at present available. From the results of the diamond borings and other direct observations, it is evident that the ore body continues below the level of the lake Luossajärvi, and that it must have a very considerable thickness there, even if it decreases downwards. As long as the data at hand are not more complete, it appears better to calculate only what quantity of ore must exist above the level of Luossajärvi. Allowing for a downward decrease in the width of the ore, in about the same way as in the boring sections, the total mass of ore has thus been estimated at 47,800,000 cubic metres, which, as the specific gravity of the ore by special weighings has been computed to be 4·5, corresponds to a quantity of about 215,000,000 tons.

The iron ore in Kiirunavaara and Luossavaara differs widely in quality, not only from most Swedish ores, but also from the majority of other ores that are mined at present. The characteristics of this ore are: an exceptionally high degree of compactness and hardness, and the fact that surfaces of fracture in it are sometimes conchoidal and highly lustrous, but very seldom at all evidently crystalline. Still more interesting than its structure is its chemical composition. The ore is remarkably free from all foreign minerals except apatite; but that occurs in very varying quantities, and is, in general, exceedingly abundant. The many different forms in which it occurs are of great interest, both from a geological, and especially from an economic point of view, inasmuch as it is from this mineral that the phosphorus in the ore is derived.

It cannot be expected that a fully reliable knowledge of the

is of fairly general occurrence in the "Statsrädet," in the "Kapten," in the northern part of the "Landshöfdingen," and at other places. It appears to be perfectly pure, and it is only on a closer examination that the small crack-fillings of apatite can be discerned, though they may raise the phosphorus percentage of the ore to several tenths.

(4.) *Highly phosphoric magnetite with apatite in nests, patches, and lenses* is by far the most common in Kiirunavaara. The major part of the following hills: the "Grufingeniören," the "Statsrådet," the "Bergmästaren," the "Direktören," the "Pojken," and the "Kapten," and no inconsiderable parts of the "Landshöfdingen," the "Professorn," and the "Jägmästaren," consist of this kind of ore. In structure and composition, this type presents very great varieties. The apatite appears in some places in the form of small grains, either widely dispersed or very close together, or as a fine network of thin veins, and sometimes in the form of very irregular meandering patches with a width of from a few centimetres to one decimetre or upwards, or again in the form of big lenticular or stratified quantities with a width of as much as 2 to 3 decimetres and a length of from 10 to 15 metres, and sometimes still more.

The apatite usually consists of very fine crystals, but is sometimes almost compact, and, especially in some of the large portions, remarkably free from iron ore and other foreign ingredients. An analysis of a sample from one big lens in the hill "Direktören" showed it to contain 40·09 per cent. phosphoric acid, corresponding to 96 per cent. of pure apatite.

It ought to be possible by sorting to separate some part of the apatite, but it is generally so closely associated with the magnetite, that an ore low in phosphorus cannot be produced in this way. The quantity of pure apatite which can be obtained by sorting is not very large.

The percentage of phosphorus in this type of ore, which is by far the most common, and thus also the most important one, is of many different grades. Thus it varies in the "Grufingeniören" from 0·4 to 2·9; in the "Geologen" between 0·6 and 2 or 3 and upwards; in the "Statsrådet" it frequently amounts to 2 or 4, and is seldom lower than 1; in the "Bergmästaren" it varies between 0·7 and 4 to 5; in the "Direktören" between 2 and 3;

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as 7 per cent. In seven samples from the lower hole (No. 4) the percentage of phosphorus does not exceed 0·046, and in one sample it amounts to 3·001.

On scrutinising the 168 analyses made in 1896 and 1897, with a view to ascertaining the amount of phosphorus in samples out of 108 different test-pits, it will be found that unsorted ore with a percentage of

0·05, or still lower, of phosphorus has been obtained in				18 pits.
0·05–0·1 of phosphorus	,,	,,	,,	18 ,,
0·1–0·8 ,,	,,	,,	,,	25 ,,
1·8–1·5 ,,	,,	,,	,,	15 ,,
1·5–6·0 or upwards	,,	,,	,,	32 ,,

The percentage of iron in 171 samples from 109 pits amounted to

45–50 in	7 pits.
50–60 ,,	12 ,,
60–67 ,,	23 ,,
67–69 ,,	26 ,,
69–70 ,,	25 ,,
Upwards of 70 in	16 ,,

In more than 60 per cent. of the pits thus examined the ore has been found to contain a percentage of iron exceeding 67.

It is obvious that until mining has been carried on for a certain length of time, no fairly accurate knowledge can be obtained as to the real quality of ores of such a varying composition. But the analyses now made indicate, as a fairly trustworthy result, that ores with less than 0·05 per cent. and from 0·05 to 0·1 per cent. phosphorus, in such quantities that they can be mined separately, occur in the hill "Vaktmästaren" and in the southern parts of the "Landshöfdingen" and the "Professorn." The quantity of such ore, which is more valuable than the highly phosphoric ore, does not seem to be great as compared to that of the latter ore. The bulk of the Kiirunavaara ore contains more than 0·8 per cent., in general from 1 to 2 per cent., and not unfrequently as much as 3 or 4 per cent. or still more, of phosphorus.

It is exceptional for the iron ore in Kiirunavaara to contain any admixture of the enclosing or other rock, so that the percentage of ore resulting from mining in this field will be exceedingly high.

The percentage of sulphur in the ore amounts in a few

analysed samples to 0·1, but otherwise it nowhere exceeds 0·088. It generally amounts to about 0·05, and was sometimes less than 0·02. The percentage of titanium varied in some ten analysed samples from 0·32 to 0·95; the percentage of manganese is very low, not exceeding 0·32.

In consequence of the extraordinary compactness of the ore, it is very hard to penetrate with the drill, but this inconvenience is more than outweighed by its extreme fissility and the consequent unusually extensive splitting of the rocks. Another advantage attaching to its hardness is that the ore does not go to dust when mined. Owing to this peculiarity and to the manner in which the apatite occurs, it is obviously impossible to remove this mineral by magnetic separators so completely as to produce an ore low in phosphorus.

In Luossavaara the iron ore is far less known, owing to the fact that it is mostly covered with soil. By means of magnetic surveys it has, however, been ascertained that the ore body is not immediately connected with that of Kiirunavaara, but commences at a point north of the shores of Luossajärvi, and extends to a length of more than 1200 metres. The width of the ore body seems to vary between 30 and 55 metres. A diamond boring near the southern end of the ore deposit has shown that the dip of the hanging-wall is at that place 81° 40′ and that of the foot-wall 70° towards the east, so that the thickness apparently decreases downwards.

The area of uncovered ore on the top of Luossavaara amounts to 5000 square metres; on the south side, where the extent of the ore has been comparatively accurately ascertained with the aid of magnetic surveys and excavations, the area has been estimated at 26,400 square metres, and on the north side of the top at 22,750 square metres. The last figure is, however, very uncertain.

In these calculations small indications of the compass in the most northerly part of the field and on the west side of the ore body are ignored. The deposit of highly phosphoric magnetite, which was discovered some ten years ago east of the top of the mountain in the vicinity of the boundary of the hæmatite-bearing schists, is still but imperfectly explored, and has been omitted in the estimate.

On the assumption that the ore body tapers off downwards, the total mass of ore at Luossavaara above the level of the lake should amount to 3,864,000 cubic metres, which is equal to somewhat more than 18 million tons, the specific gravity of this ore having been calculated to be at least 4·7.

The great bulk of the ore in Luossavaara, as far as hitherto known, is comparatively low in phosphorus, and is very analogous to the ore described as type No. 2 in Kiirunavaara. It consists of a compact, hard magnetite, or in places of magnetite mixed with hæmatite, sometimes without, sometimes with lustrous surfaces of fracture, and often containing cavities covered with rust, sometimes so numerous that the ore is quite porous.

More recent examinations have proved that the ore in Luossavaara contains somewhat more phosphorus than what was previously supposed to be the case. It has been found that the ore even here at some places contains apatite, sometimes in the shape of disseminated grains of varying size, sometimes finely impregnated. Thus in the southernmost test-pit a grey ore with about 6 per cent. phosphorus occurs close to the foot-wall, while in the same pit, in the neighbourhood of the hanging-wall, there appears a black, lustrous ore almost quite pure, two samples of it having shown only 0·344 and 0·074 per cent. phosphorus. In another pit, situated in the line of the diamond boring, two sorting experiments resulted in two different qualities of ore being obtained; the percentages of phosphorus are in the one case 0·039 and 0·070, and in the other 0·065 and 0·265. Just above this pit one of the qualities of ore that have been sorted out contains no less than 1·650 per cent. phosphorus. In other pits, from which samples have been taken, the amount of phosphorus is generally low, but varies very much. Unsorted ore with less than 0·05 per cent. of phosphorus has been observed in one pit only, and, in the sorting, an ore of this kind has only been produced in three or four pits.

Judging from the results of an examination of small surface pits, there is every reason to believe that no inconsiderable quantities of ore can be obtained in Luossavaara with the low percentage of phosphorus requisite for the acid Bessemer process, but no estimate of these quantities can at present be made, even approximately.

DISCUSSION.

Mr. W. Whitwell (Hon. Treasurer) was very glad of the opportunity of saying two or three words, if only in acknowledgment of the exceeding kindness that was shown to them by those who invited them to see the wonderful deposits in the northern part of Sweden. For many years, he might premise by saying, it had been his privilege to use the ores from Gellivaara; but up to the present time, naturally till the railway was made, as regarded the ores of Kiirunavaara and Luossavaara that was a matter in some degree for investigation, examination, and analysis, that he could not now pretend to go into. His firm had used nearly 100,000 tons of Gellivaara ore. It was mostly the best quality—the A quality—that had been sent to his firm, and it might be a little interesting to all those who were steel makers and steel users to know what the character of this ore had proved to be from careful analysis in the case of the investigation of every cargo. The deliveries commenced in 1888. The first cargo they received contained 69·06 per cent of iron, 0·01 of sulphur, and 0·004 of phosphorus. In 1889 they had four cargoes of iron ore which contained 68·845 of iron on the average, and phosphorus 0·044.

In 1892 they had a number of cargoes averaging 68·18 of iron, and 0·032 of phosphorus. In 1893 they had a number of cargoes with 69·31 of iron, 0·096 of sulphur, and 0·0164 of phosphorus. In 1894 they had a number of cargoes with 68·492 of iron, and 0·0141 of phosphorus; and then they came on to 1895, showing the iron ore almost identically the same, and he need not repeat it; and the phosphorus during the last four years was 0·0225, 0·020, 0·030, and 0·031. There was only one cargo delivered this year, with its 0·031 of phosphorus. This included all the A ore received by the buyers during these nine years, and it was absolutely exact analysis of the whole of the cargoes received. The samples were selected during the discharge at W. Whitwell Co.'s wharf by the sampler of Pattinson & Stead of Middlesbrough. It showed altogether a very excellent material, very free from apatite, and although slightly more refractory than the best Spanish, and African, and South Spain ores, it was excellent to use as a mixture, and gave perfect results on the analysis of the

ore deposits of Swedish Lapland with Victoriahafn, on the Ofoten Fjord, on the Norwegian coast.

Victoriahafn is situated at the east end of the Ofoten Fjord. It is a fine sheet of water of some square miles in extent. The depth of water is ample to allow steamers to lie along wharves, and the only difficulty to be overcome is the considerable rise and fall in the tides, which vary from 12 to 20 feet at neap and spring.

From Victoriahafn to Kiirunavaara is a distance of about 110 miles. The first 20 miles lie through Norwegian territory, ascending from Victoriahafn along the southern side of the Rambokken Fjord, through the Hundthal, to the plateau of Katarak, where the boundary between Norway and Sweden is passed. The plateau is between 2000 and 3000 feet above sea-level.

A good deal of work has been done along this Norwegian section of the railway by a now defunct English company. It is understood that the Government of Norway have purchased the work from the company and intend to adapt the line so chosen to the railway now under construction. Work is now in progress on the Swedish side of the boundary, and also, I think, on the Norway side. The material for the Swedish engineers is at present being landed at Botten, a small village on the east end of Rambokken Fjord above mentioned, whence it is conveyed by country carts a few miles up to Hundthal, some 500 feet above sea-level, and thence by pack-horses to the first engineers' camp on the plateau, at a place called Vassajowa.

Having been favoured with an invitation from the Gellivaara Company to visit the deposits of Kiirunavaara and Luossavaara, I decided to attempt the route from Victoriahafn in order to see what sort of country lay between the mines and the coast. Leaving London at the end of July, I crossed from Hull to Christiania, thence by rail to Trondhjem, and by steamer to Svolsvaer, in the Lufoten Islands. There I hired a small steamer which took me to Victoriahafn, where I landed on Wednesday the 10th August. The terminus of the railway is of course to be at Victoriahafn, but all operations are now being conducted from the little port of Botten, at the east end of the Rambokken Fjord. Steaming on to this spot through the picturesque gulf,

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and so we had experience of Lapland morass and wilderness untouched by man.

Torne Traske is a magnificent sheet of water 50 or 60 miles long, and in parts some miles wide. It stretches from within a short distance of the border between Sweden and Norway to the south-east, and it is the reservoir whence flows the great Torne River, which joins the Gulf of Bothnia at Haparanda. The water is wonderfully pure. Doubtless there will shortly be steamers on this lake and hotels along its banks; but at the present moment it is uninhabited and silent.

The boat in which we embarked was of primitive construction and without shelter. Fortunately the weather was quite fine, so we were able to land to cook our meals, passing the nights in the boat, for the mosquitoes quite prevented sleeping on land. We took from five o'clock on the 12th to two o'clock on the 13th to row down the lake, whence we emerged into a succession of long and wide reaches of water connected by rapids. At some of these we had to unload the boat and let it down with ropes. We eventually reached the first settlement at a place called Kiiruvaara, 10 miles north of Kiirunavaara. Here we were hospitably received by the Finns, who inhabit that part of the country.

The railway is to follow the south bank of the Torne Lake, and to an unprofessional eye the route seems well chosen, as there is ample slope between the somewhat monotonous hills and the lake, requiring but little rock-cutting and tunnelling.

Kiiruvaara is a pleasant little spot of some twenty or thirty houses situated on one of the inlets of the Torne River. The wooden houses are substantial and well built, there are considerable stretches of pasture land, and it was agreeable to arrive at so pretty a place after three days of wilderness and solitude. From Kiiruvaara we walked 10 miles to Kiirunavaara, where we arrived on the 15th, and found welcome and hospitality from the Gellivaara Company's representative.

I was informed that the railway will take four years to build, and that it will cost one and a half million of pounds sterling. It is estimated that 1,200,000 tons of ore will be exported every year. This means a daily transport of 4000 tons, requiring eight trains per day. On the one hand, considerable hindrance

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ay be found in regularity of work during the winter months; [illegible], on the other hand, the continued daylight of twenty-four hours during the summer will give exceptional facilities for [illegible] work.

The PRESIDENT, having proposed a cordial vote of thanks to [illegible], announced that the Secretary would be very glad to receive any further remarks in writing on Mr. [illegible]'s paper. The following paper was then taken as read:—

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EXPERIMENTS MADE WITH A MOTOR USING BLAST-FURNACE GAS.*

By AIMÉ WITZ.

THE object of these experiments was to study the practical condition of working of a one-cylindered gas engine of great power, fed by the gas from blast-furnaces using coke.

A sufficiently extended trial was necessary in order that it might be proved from it whether the gas from blast-furnaces can be directly employed in gas motors, and whether such gas allows of continuous and regular work, whatever may be the variations in quality, in richness and in pressure, and in spite of the abundant dust which it brings with it. This proof also ought to include a very exact determination of the consumption of gas, oil, water for the cylinder, and of water for the apparatus for washing the gas, under normal working conditions.

Mr. A. Greiner, the managing director of the Cockerill Company, did me the honour of confiding to me the direction of these trials, and put at my disposal everything necessary to bring them to a successful issue.

Messrs. Hubert (Professor at the Liége University), Bailly and Kraft (engineers to the Cockerill Company), and E. Delamare-Deboutteville, were good enough to become my coadjutors, and to assist me with the numerous data it became necessary to

* This paper embodies the report of experiments with a blast-furnace gas engine of 200 horse-power, made at Seraing, which was promised by Mr. Greiner at the last meeting of the Institute. The experiments were made by a prominent expert, Mr. Witz, of Lille, France, and show that the consumption of gas, which was expected to be about 4 cubic metres per effective horse-power, was not more than 3·329 (115 cubic feet) after 24 hours' continuous trial, showing the immense benefit derived from the direct use of blast-furnace gas in engines. These very interesting results induced the Société Cockerill to decide to build a 500 horse-power blowing engine.

machine; another noted the admissions of the gas. A Richard register traced the speed curve: the line 600 corresponded to 125·3 revolutions, the line 400 to 83·5 revolutions; one division of the ruled paper was thus equivalent to a variation of 2·09 revolutions per minute. A Crosby indicator allowed of taking the diagrams and of calculating the work indicated. Thermometers gave the temperature of the air and of the water, both entering and leaving the cooling-jacket of the cylinder. The number of revolutions from the indicators, and the various temperatures, were taken every half-hour, and at the same time a diagram was taken, and the load of the brake noted. Our tables of the trial, therefore, permitted every variation of the working of the engine to be followed. The amount of water used in the cylinder and scrubbers was measured in gauged receivers.

The volume of gas consumed was determined by the aid of the bell of the gasometer, which had been previously graduated. For this purpose the circumference of the bell was measured, in order to arrive at its interior diameter; there was then placed on the tank three vertical measuring staffs, before which an index was arranged. These measuring staffs were placed at 120° the one from the other, and three observers noted simultaneously at a given signal the position of the index; by taking the mean of these three figures, the error which might have resulted from an oblique movement of the bell was corrected. These measures were repeated five times, each time for twenty-nine minutes' work. Each operation coincided with a removal of gas, and these samples, contained in hermetically-closed glass flasks, which I carried to my laboratory at Lille, permitted of the determination of the mean calorific power of the gas at the exact moment of measuring the consumption of the motor. Knowing the atmospheric pressure and the temperature, the volumes measured were readily reduced to 760 mm. and 0° C.

Finally, a certain quantity of oil and grease was put at the disposal of the driver of the machine at the commencement of the trial; what remained at the conclusion was weighed, the lubricators being furnished identically in both cases, and the weight consumed was determined by difference, without taking into account any that might be recovered.

Consumption of Water.

At the scrubbers:

Per hour		5388 litres
Per cubic metre of gas	(about)	9 „
Per effective horse-power hour	„	30 „

At the motor cylinder:

Per hour		13,000 litres
Per effective horse-power hour	(about)	72 „

The total consumption of water per effective horse-power hour is about 102 litres.

Consumption of Lubricants.

In twenty-four hours:

Oil		68 kilos.
Grease		2 „

Per effective horse-power hour:

Oil	(about)	15 grammes
Grease	„	2·3 „

An extract from our tables of results will show the regularity of work of the engine.

Taking as an example the interval from the 14th to the 24th hour, on the 19th July, and bringing together the speed, the admissions and the loads.

The figures which have been given do not require any long comment. We need only observe that the engine developed 181 horse-power, with the suppression of more than a tenth of the admissions, thus preserving the elasticity necessary for good work.

The work was continued during 24 hours, without interruption and almost without variation, since the general average of the trial (181·16) does not differ from the average of the five tests of the consumption (181·82).

The consumption of gas also does not greatly differ from hour to hour, and the calorific power of the gas remains in the neighbourhood of 981 calories; the average consumption of 3·329 cubic metres per effective horse-power is remarkable, I would almost say, unhoped-for. As to the regularity of work, this is well shown by the Richard indicator diagram. On the other hand, the consumption of water and of oil is much less than

ladies also being present in anticipation of the visit of King Oscar.

Sir JAMES KITSON, Bart., Past-President, said, in the temporary absence of their President, he had to announce that Mr. Stead's paper on "Brittleness in Soft Steel produced by Annealing" would be read and discussed. The discussion would also include Mr. Stead's paper on the Crystalline Structure of Iron and Steel, and the papers by Mr. Ridsdale and Mr. Saniter read at their last meeting.

The SECRETARY then read an abstract of Mr. Stead's paper.

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which has been laid with stones of no regular form. Each polygonal area in metals represents the section of a crystal, the true terminal angles of which at the time they grew or were developed not being able to form owing to mutual interference of growing contiguous crystals. These polygonal areas in reality represent the grains or crystals seen on any rapidly fractured surface of a metal.

Practical men commonly describe such fractures in steel of "coarse" or "fine" structure as "finely" or "coarsely crystalline," but the terms "fine" or "coarse grained" are also used. Some engineers call a fine structure "granular," and a coarse one in which large bright faces are visible as "crystalline." We must remember, however, that whether the crystalline grains in a metal are large or small, the metal as a whole is equally crystalline, the only difference being that there are a greater number of separate individuals in one case than in the other. The polygonal masses of irregular shape when completely isolated much more resemble grains than crystals, and it appears more reasonable to call them the former than the latter. To be more exact, the term "crystalline grain" correctly expresses their character. As long, however, as it is clearly understood what is meant by terms, it is not of great importance which is used.

In the remarks which follow the term "grain" will be used instead of crystal, and it must be understood to mean a grain the mass of which is crystalline, the molecular crystals of which it is built being all of same orientation in the whole of its mass.

It has been repeatedly proved that many cubic crystals of minerals possess the property of being split up more readily in some directions than in others, and these are always at right angles to and parallel with a cube face. It will be seen, then, that the number of directions in which a true cube crystal can be split must be three, all of which are right angles to each other. The property of crystals to split up in this peculiar way is what mineralogists call cleavage.

Iron crystallises in the cubic system, and the crystalline mass of every separate grain in a bar of iron is more liable to split up in these three directions than in any other. When we talk of the orientation of the crystals of a metal, we mean the direction of their cleavage planes, and their relation to each other in the crystalline granules of which the metal is an aggregation.

The alloy of copper with a very little bismuth in which the grains of copper are enveloped with a brittle constituent is an excellent example of inter-granular weakness.

Professor Arnold has found that occasionally in steel castings the grains are more or less enveloped with an easily fusible scoriaceous matter, and the writer has proved, as was rightly assumed by Arnold, that the line of fracture actually follows the scoriaceous envelopes. The hard white and brittle envelopes of carbide of iron which surround the grains in steel containing above 1 per cent. of carbon, are the principal lines of weakness, and it is through the centre of these brittle envelopes the fracture mainly travels when the steel is broken.

There is another character of inter-granular weakness, in which, so far as we can see at present with the appliances at command, there is weakness, yet no envelope of a brittle constituent is present. This is particularly marked in certain annealed steels containing phosphorus. Professor Arnold believes that the crystalline grains in the mass of such metal on cooling contracts unequally, and tend to draw apart, leaving the junctions not perfectly jointed, or in a state of unnatural tension. Whatever the cause may be, it certainly happens that in such material the fracture follows mainly the granular junctions.

We see, then, that inter-granular weakness may be divided into two main classes:—

1st. When brittle matter foreign to the character of the mass of the grains envelops them.

2nd. When the brittle envelope is absent, and the grains from some cause not clearly demonstrated are not perfectly cohesively united.

Cleavage * Weakness.

The second character of weakness in metals is that in which the weakest line is not between the grains, but is that represented by the true cleavage planes through the mass or body of the grains. Example was given in the paper read at the last meeting of cubical forms which had been split from a large

* This term "cleavage" has been substituted for "inter-crystalline" at the suggestion of mineralogists.

Fig. 2 represents diagrammatically the position and orientation of the molecular crystals in a few contiguous grains, A, B, C, and D. The little squares in each tilted at various angles represent the manner in which the little molecular cube crystals may be oriented in a vertical section of pure iron.

In A the cubes have their upper faces parallel to the surface.

In B they dip at an angle of about 10°
In C „ „ „ „ „ 20°
In D „ „ „ „ „ 30°

The upper line represents the etched surface of the section through the faces of the little cubes, some of which are inclined

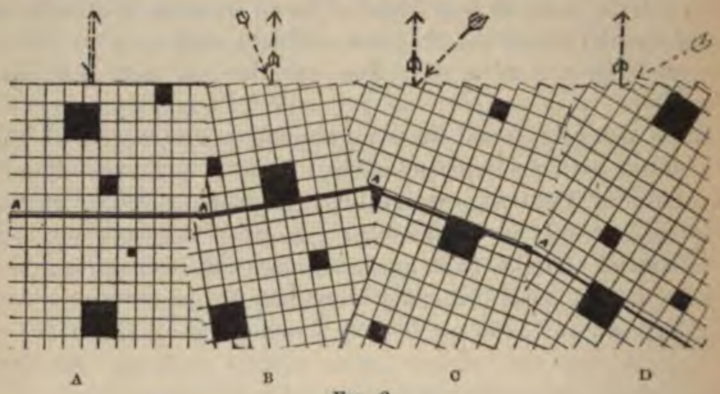

FIG. 2.

so as to form a series of little steps, just as in reality they are found after polishing and etching.

The thick dark line gives the direction in which fracture would be most readily effected from right to left.

The dotted lines at the upper part represent the angle at which the light must fall in order that it may be reflected vertically. The thin dots represent the incident rays or those which fall on to the surface, the thick dots the reflected rays. The angle made by the incident and reflected rays, divided by two, gives the angle of inclination which the upper faces of the molecular crystals bear with relation to the surface of the metal section.

The dark squares, some of which are large and others smaller, illustrate the manner in which the nitric acid selectively digs

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The crossed lines represent the cleavage planes in each grain. The coarse structure, Fig. 4, represents crystals heterogeneously arranged, whereas in the finer structure, Fig. 3, they are more symmetrical and the cleavages run in almost parallel lines. The latter type would be easily broken up, whereas the former would be strong and tough.

It is of course well known, all other things remaining constant, that it is advisable to obtain structural and other steel as finely grained as possible. The following illustration is only introduced to show that crystalline arrangement may completely reverse this

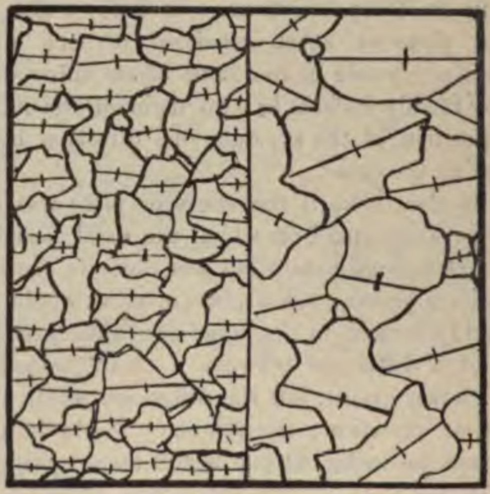


FIG. 3. FIG. 4.

order, so that a coarse-grained metal may be stronger than one of finer grain.

The truth of the foregoing statement has been fully demonstrated in the research of the writer in his experiments at Middlesbrough and elsewhere.

It will be seen, then, that brittleness may be caused by the crystals arranging themselves in symmetrical fashion in contiguous grains.

Fortunately, *as a rule*, in iron and steel they do not grow or build themselves in such order, but are heterogeneously arranged. The illustration No. 17, in the paper on crystalline iron, gives

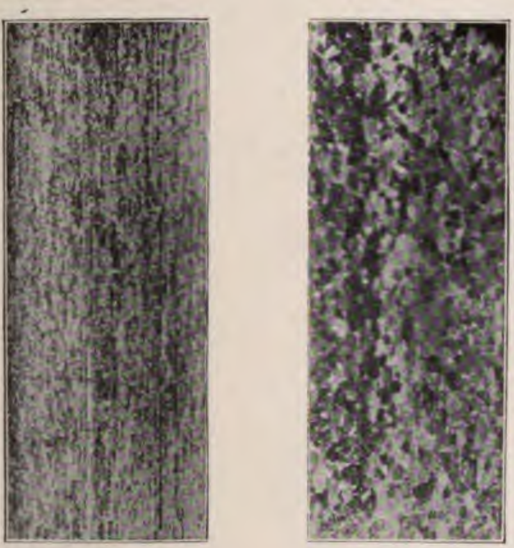
PLATE VI.

FIG. 1.

[illegible]

PLATE VII.

Rolled sheet. *Do.—Annealed.*

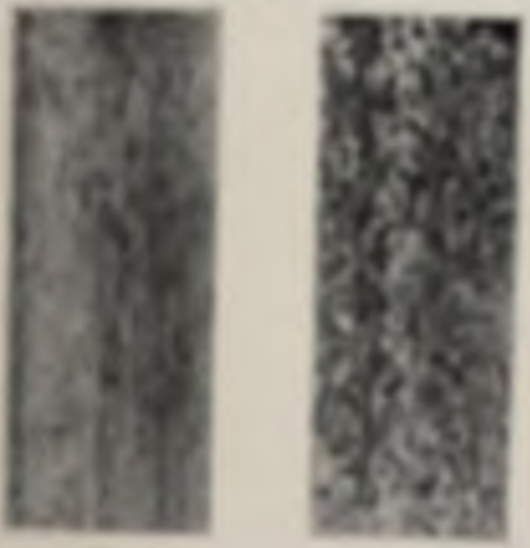


(*a*) (*b*)

FIG. 6.

$\times$ 30 – 0.

PLATE VII.



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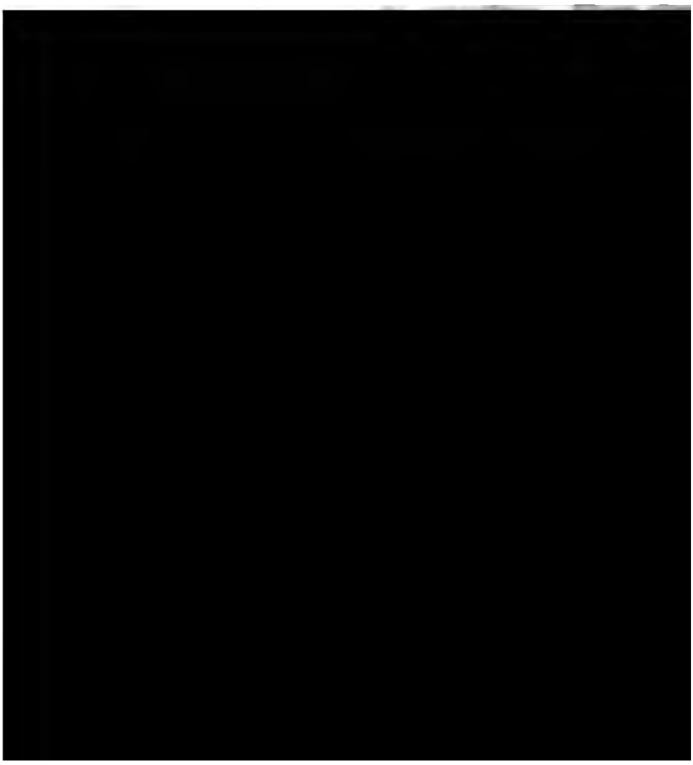

In the laboratory trials of the writer the coarse granular structures obtained by annealing pure iron at 700° C. could not be broken by a sudden blow; and on examination microscopically, the etched grains, sometimes of large dimensions, were found, by the way they reflected light, to have their cleavages at other than right angles to the surface. These samples could be bent over upon themselves without fracture.

It was often found, however, that a coarse-grained bar, after bending to right angles, broke on straightening, whereas the same bar with fine grain could be straightened without breaking.

Although the trials in the laboratory did not give what may be called brittle crystalline iron, it is possible, if they had been repeated, or a sufficient number made, we might in time have obtained one which was so. Occasionally we have met with bars of practically pure Swedish material which were exceedingly brittle, and in which the cleavages were generally at right angles to the outer surfaces. Unfortunately, their previous history and the nature of the mechanical treatment they had been subjected to could not be ascertained, excepting that they had been annealed for a long period at a temperature under 700° C., and this was determined with certainty by microscopic examination.

Much work has been done with the endeavour to produce at will material with this brittle crystalline organisation, but so far we have not been able invariably to do so. Mr. W. R. Lysaght of Wolverhampton has co-operated with the writer, and has done a very large amount of practical work at his suggestion, having annealed hundreds of samples, and rolled many samples of steel under different conditions.

One series of trials was most interesting and instructive.

Several tin-plate bars were annealed in a close box for forty-eight hours at about 700° C. These when cold were cut in two, one half of each being retained for examination, and the others re-annealed for forty-eight hours. These when cold were again halved, and portions of each were annealed a third time. All the samples were examined mechanically and microscopically.

The size of the grain in the centre of all the bars after repeated annealing was larger than in the same bars before annealing; but, after the first annealing, all the bars were enveloped with a coarsely granular layer. On polishing the surfaces, and then

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Brittleness in Annealed Sheets.

1. The examination of a large number of annealed sheets has revealed the fact that when their thickness is less than 18 B.W.G., brittleness is never developed, and that it is *occasionally* developed in sheets of from 10 to 20 B.W.G.

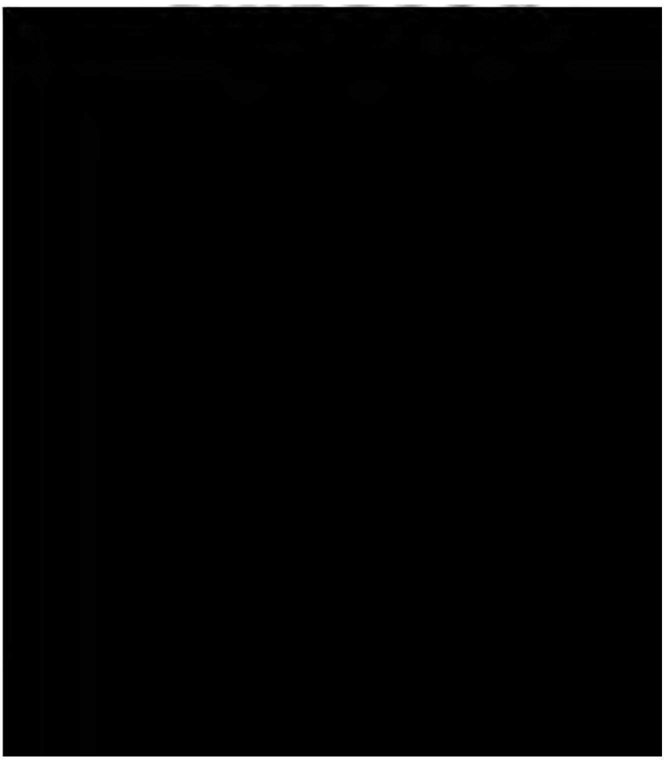
2. That the preponderating quantity of thicker sheets, which are not readily broken when they leave the annealing pots, and which cannot be classed as brittle, after heating from 400° to 500° C., and being subjected to jar or shock, which may or may not be sufficient to give a permanent set, almost invariably causes a development of a brittle character. The character of the weakness is sometimes inter-granular, but more frequently inter-crystalline. The lines of weakness in the former take no special direction, and the sheets break up exactly like cast iron. The weakest positions in the second class are invariably in certain fixed directions, viz., *at angles approximating to 45° to the direction the sheets were rolled*, and at right angles to the surface of the sheets. In other words, the weak lines correspond to the three directions of cleavage in a cube, having four faces at 45° to the edges, and two faces parallel to the surface of the sheets.

Such material can be bent and hammered close together when the bending is done longitudinally or at right angles to that direction, but it breaks off readily when bending is attempted at angles of 45° to the direction in which the plates were rolled.

The peculiarity of breaking up in rectangular positions has long been noticed, but it does not appear that notice has before been taken of the invariably fixed relation which exists between the lines of fracture and the direction of rolling.

What is the cause of this peculiar relation?

It is evident that the rolling is the initial cause, but in no case whatever have the rolled sheets previous to annealing shown any tendency to break up in rectangular directions. The rolling of all these sheets is done when the steel is at a comparatively low temperature, about 600° C., and, as one would naturally expect, a fractured surface invariably presents a fibrous appearance, and



plates, and when such etched specimens are distorted or are pulled out, for these plates to slide over each other.

It appears probable that the rolling causes a sufficient number of the molecular crystals or groups of such crystals to be arranged in the position shown in Fig. 5 to form dominating centres of crystalline attraction. When a sheet bearing such an impression is subjected to a suitable annealing process, a systematic marshalling of what is possibly the greater mass steadily form about these centres with the formation of the relatively massive crystalline grains which have the same or nearly the same orientation throughout the whole sheet.

It is difficult to believe that the greater mass of the molecules are arranged as shown in Fig. 5 *before annealing*, for if they were, there would certainly be rectangular weakness, which we know there is not in sheets from the rolls.

Of course the above explanation is purely hypothetical and may require much modification hereafter when we have obtained more experimental data.

One very fine example of very gross granulation was met with in an annealed plate. It had been rolled to 16 B.W.G., and afterwards annealed for forty-eight hours.

It had the following composition :—

	Per Cent.
Carbon	0·035
Manganese	0·331
Silicon	trace.
Sulphur	0·019
Phosphorus	0·057

It is remarkable for its low sulphur and carbon content. Probably the carbon in the rolled sheet was not less than 0·09 per cent., the difference, 0·055 per cent., having been oxidised in the annealing. Fig. 7 is reproduced from a photograph, natural size of this sheet, after etching with nitric acid, 1 to 10 water, for ten minutes.

On looking at the original illuminated with vertical light, about one-third of the granules appeared bright, and on moving the plate to angles of 10° in different directions, nearly all the grains became successively bright—a proof that the molecular crystal faces were nearly coincident with the flat surface of the plate.

slight, and they approximate closely to right angles to the surface.

There was one small grain at the centre of the lower portion with crystal faces at 45° to the surface, and, just as might have been expected, cleavage from opposite sides stopped on each side of this grain, and it was only after bending this grain backwards and forwards that the two pieces could be separated.

Strips cut from this sheet could be pulled out and elongated nearly 30 per cent. before breaking, and stood much punishment supplied in all directions other than at the cleavage lines of weakness.

By heating to 900° C. for one minute, all the peculiarities vanished, and it became fine grained and tough in every direction.

II. *Inter-Granular Weakness.*

There has not been sufficient evidence to enable us to form dogmatic conclusions as to the cause of inter-granular weakness, but in the two or three cases examined the phosphorus was found to be excessive. One very brittle piece contained :—

	Per Cent.
Carbon	0·040
Manganese	0·431
Silicon	trace
Sulphur	0·063
Phosphorus	0·263

Re-annealing for forty-eight hours did not restore its good qualities, but it changed its character, the line of fracture traversing both through the grains and at their junctions.

How to Prevent Brittleness.

The whole study and work on the subject of crystalline iron was made in order that we might ascertain the conditions leading to the development of brittleness, and so find out what to avoid, and also to ascertain if anything could be done afterwards by any special treatment to convert brittle material into steel, tough and reliable. In the more recent investigations of brittle sheets the following facts have been noted :—

1st. Occasionally one end of a sheet may be tough and good

It has already been mentioned that sheets of 22 and higher gauges never develop rectangular brittleness, and that it is only in the thicker sheets it is obtained.

What is the cause of this difference? Does the rolling continued beyond a certain point destroy the latent arrangement set up before that point is reached?

This question we cannot answer with our present knowledge.

The whole problem is surrounded with many practical difficulties, and it is certain that until we have means at hand of practically controlling and determining the temperature for forty-eight and more hours of the annealing pots it will be useless to continue the study. The fact that contiguous parts of the same sheets differ materially in brittleness, the composition being the same in each part, and that different parts of the pots vary in temperature, would lead us to believe that proper temperature is the all-important factor.

The one important point which we may consider to be established is, that phosphorus should not be allowed to exceed about 0·08 per cent.

A sample of steel which was exceedingly brittle in rectangular lines, and which, although it was annealed repeatedly, still maintained its brittle cleavage character, contained—

	Per Cent.
Carbon	0·11
Manganese	0·345
Silicon	trace
Sulphur	0·090
Phosphorus	0·128

In conclusion, it must be admitted that the study of this most important subject is not only of the highest scientific interest but of the greatest practical importance. It would be well if more attention was paid to it, and it is hoped that the results recorded in this note will stimulate others to follow up the investigation.

The writer acknowledges with gratitude the valuable co-operation of Mr. W. R. Lysaght.

important papers that had ever been presented to the Institute. It would take one or two years to soak in before steel metallurgists could fully appreciate its value. He had read it more than once with the greatest possible interest, and there was no doubt Mr. Stead had struck out a line which must be carefully followed with reference to the crystallisation of iron. With the bulk of the paper and the facts contained therein, so far as he had covered them personally, he was almost entirely in accord with Mr. Stead. But there were one or two points open to criticism, and upon these he would like to make a few observations, because they were rather important, and he much regretted that Mr. Stead was not present, for he always welcomed criticism. Mr. Stead had remarked that when he (Professor Arnold) determined the crystallising point of iron he had concluded that crystallisation took place at 750 degrees. What he did say was that the crystallising point of iron, the point at which the crystalline activity was at the maximum, was coincident with Ar2, and that it could not be fixed to any definite temperature, because so far as they could observe pyrometrically it ran from 720 to 750 degrees. Ar2 presented a prolonged evolution, and he believed it to be a duplex point, because it generally exhibited two maxima. Beyond that point, Mr. Stead's results seemed very closely to have proved still more fully the fact that 720 to 730 degrees was the crystallising point of iron.

Then Mr. Stead gave some very remarkable results in changes of structure said to have taken place as low as 600 degrees Centigrade, which appeared to be opposed to the theory that crystallisation could be associated with the point Ar2. But most of the samples were distorted by mechanical means before they were heated, and under such conditions any metal had a tendency to return to its normal crystallisation when raised to a low red heat. That fact might largely explain Mr. Stead's results. At any rate the temperature at 730 given by Mr. Stead came so close to Ar2 that they might regard Ar2 as the crystallising point of iron.

There was just a point with regard to the nomenclature adopted in the paper read by Mr. Stead at the last meeting with which he could not agree. In the paper put before them that morning Mr. Stead had made the modification which he had suggested

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called grains they must do away with crystals altogether. He suggested that the drawing of Mr. Andrews might be published in the *Transactions* of the Institute.

In introducing the paper at the last meeting in the few minutes allowed Mr. Stead in which to do it, he stated that he had obtained results which led him to believe that there existed —he believed his words were—"a kind of Alpha, Beta, and Gamma iron." It was very necessary to explain clearly in the first instance what Mr. Stead meant by that. It was necessary to remember that Mr. Stead's supposed modifications were in no way connected with the Alpha, Beta, and Gamma controversy which had been raging so long. The Beta iron of the allotropists had reference to an alleged flint hard modification of iron to which it was stated the hardening of steel was mainly due. Mr. Stead's idea in making his statement was that there might exist two or three modifications of iron *all soft* but differently crystallised. He thought that was perfectly possible; but they had as yet hardly an atom of proof that such was the case. Mr. Stead's ground for that statement seemed to be the size of the crystals formed at varying temperatures. He (the speaker) thought it would be impossible to make any allotropic classification based on the size of crystals. To prove the existence of those allotropic crystals two things must be done: (1) trimorphism must be proved micrographically; (2) it must be shown that the various crystalline modifications presented different mechanical properties. Now, if there were really soft Beta or Gamma irons, those should be crystallised so as to be recognised by the microscope. Until that was proved they could not accept the existence of those allotropic soft modifications. Something more practical must also be done.

If the proof of the existence of allotropic modifications was to be of any use, they must use the testing-machine. The testing-machine was the House of Lords of metallurgists, and there was no appeal from it. If they said any particular metal was Beta iron, and yet could not recognise it mechanically, it was of little use knowing anything about it. When they turned to Mr. Stead's mechanical tests they found that his iron when quenched (1) at a white heat, (2) just above Ar2, and (3) below Ar2, all gave the same mechanical results, yet Mr. Stead suggested that

on the table, he noticed, however, was not an ordinary plain annealed sheet, but one that had been galvanised after annealing; and he should like to ask Professor Arnold whether the crystallisation which they saw in that specimen might not have been produced by the acid bath, in which it had been immersed previous to being galvanised.

Professor J. O. ARNOLD thought that such change was possible, but he did not think that this specific case was due to it. For instance, thin cold steel which was pickled, after pickling was absolutely brittle. If taken up to a low red heat, it bent double; so that pickling must affect the crystals. But he did not think in Mr. Stead's sample the brittleness was due to pickling. He thought it was due to mechanical effect producing the peculiar crystallisation suggested, or rather proved, by Mr. Stead.

Mr. G. J. SNELUS, Vice-President, said the question was whether it was not possible that the zinc itself had formed the alloy right through the mass. He had worked on the alloys of zinc and iron, and he knew how rapidly the zinc would find its way right through the body of the metal; and he strongly suspected that the crystallising effect was due to zinc.

The PRESIDENT said the question still remained, Why should thousands of tons of sheets stand certain tests easily, and the same class of sheets fail in other cases, though dealt with in the same way?

Professor HOWE said that this phenomenon which had been brought forward by Mr. Stead was of scientific as well as technical interest. This rectangularity, and especially the position at an angle of 45°, with the length of the plate, *i.e.* with the direction of rolling, pointed very strongly to the inference that this cleavage had been developed in the rolling, because if the rolling were to develop a cleavage at all, it should have this position of 45° with the direction of rolling. In rolling there was a powerful longitudinal pull; and it was familiar to the members that, when a test bar was pulled in two in a testing machine, the facets of the fracture were at an angle of

PLATE X

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years ago he had some experience in tin-plate works, and they were constantly being troubled with a number of failures, due to this extraordinary fracture of sheets at 45°, and they were not able to get at the bottom of it. It occurred not only in tin plates, but also in black plates, so that the point raised by Mr. Snelus, that it was due to the alloying of the zinc with the iron in galvanising, could not be the cause. They often had great batches of sheets without a single failure, and then, without any apparent reason, large numbers would fracture in stamping, &c. Analysis did not explain the matter.

The work of Mr. Stead seemed to have practically proved that, under certain conditions of heating and rolling, a molecular change took place, which was the cause of this weakness, and that, by further special heat treatment, the ductility of the sheet could be largely if not entirely restored. To do this commercially was no doubt a very difficult problem, as the uniform heat treatment of large bulks of material was always a very difficult matter; but now that the key to the solution had been found he had little doubt that the great ability and untiring energy of Mr. Stead would lead to a speedy solution of the matter on a commercial scale.

Mr. ANDREW M'WILLIAM said he had carefully read both Mr. Stead's and Mr. Saniter's papers. With the bulk of the material he entirely agreed; but he wished to support Professor Arnold in connection with this matter of nomenclature. Mr. Stead objected to the term "crystal" because it was not sufficiently accurate, and quoted Mr. Bauerman's definition of "crystal," but that was an ideal which was very seldom attained; and if Mr. Bauerman's book was read carefully, he recognised that fact, and that the majority of the cases they had to deal with were more or less imperfect crystals. Nowadays they took the outside forms and facets more as a guarantee of what the molecular structure was. He preferred to use the term "crystals" for those little bodies, a term which had a definite idea; and if they kept before them the idea of molecular structure only, then they might continue its use. If any one felt a difficulty in using this term they ought not to go to the term "grain," which was only accurate because it was so indefinite in this case that they could

to find a hard electro-iron in Sheffield. Before he came away he could not get a sample of this iron to test it properly. But people said it was sometimes very hard, and would scratch glass. He took some of the Swedish wrought iron, and he tested that, and it scratched the glass on the door of a private room; so that to say that a thing will scratch glass was not definite enough. That was a matter which really required investigation. He would like to have a piece of this hard electro-iron, so as to test it, and see what its hardness was, and what comparison it had with the ordinary soft iron. The electro-iron was excessively brittle before heating to a high temperature, and that might have led to the belief that it was hard; and the scratching of glass would not do at all—they must do it with the ordinary scale of hardness.

Then with respect to Mr. Saniter's allotropic modification. So far as he could see, Mr. Saniter's allotropic modification rested on crystallographic grounds, and by trying Mr. Saniter's angles, and fitting them to the cubic system, he did not think there were sufficient grounds for assuming dimorphism. The angles in the faces could be matched by faces or sections of cubic crystals, the angle in No. 20 being exactly a face of either a tetrahedron or an octahedron, which were, of course, typical forms of the cubic system. No evidence had yet arisen to lead beyond the opinion expressed by Dr. Sorby, the pioneer investigator of the micro-structure of rocks and of metals, that the crystals observed in sections of iron probably consisted of interfering cubes and octahedra, where they indicated any crystal faces at all.

On the question of nomenclature they must provide something instead of Mr. Stead's terms. They still retained the name "crystal," and the phrase "inter-crystalline cohesion" for the cohesion between different crystals, and not as in Mr. Stead's use of it, between parts of the same crystal. For his term of "inter-crystalline weakness" we would simply use the ordinary term "cleavage," as understood in mineralogy. The iron had developed a cleavage, just as the fluorspar sometimes developed it and sometimes did not, and as the analogy between steel and certain igneous rocks had been fully established, they adhered in Sheffield as strictly as possible to the present usages of mineralogy, thus avoiding the endless confusion obviously created in a science by each writer acting on the assumption that "as long

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Professor ROBERTS-AUSTEN said, with reference to the observations of his friend Mr. M'William, that it was some years ago since he worked in his own laboratory, and he only wished he were working there now. Professor Austen had made a great many analyses within the last six months. He had taken the greatest possible pains to eliminate the impurities as far as might be possible. It was easy to deposit iron electrolytically of almost any degree of hardness. A variety of iron might be deposited which topaz would not touch; or, on the other hand, a variety of iron could be deposited which, while it appeared to be perfectly coherent and metallic, could be readily scratched by calcite. How much the hardness depended upon the presence of hydrogen he was not in a position to say. He agreed in the absurdity of talking of hard and soft. There were all ranges of hardness from that of topaz down to that of calcite.

CORRESPONDENCE.

Mr. A. H. GÖRANSSON, of Sandviken, sent the following communication:—

At the meeting in Stockholm the sample of brittle steel, which was shown as an illustration to Mr. Stead's paper on "Brittleness produced in Soft Steel by Annealing," was handed over to me by the kind permission of the President, and I now beg leave to return it with thanks after having made some experiments on it. I have cut the piece of sheet in two halves, and changed the quality of one of them to toughness and a fine grain through giving it a short white heat of about one minute's duration. The possibility of changing coarse steel in this way has long been known in our annealing shop, and I observe from Mr. Stead's paper that he is also aware of it. It might all the same interest members of the Institute to see it now practically carried out.

Regarding the cause of the original brittleness I will not venture to go into the abstruse theories propounded regarding the influence of rolling. I wish only to say, that I doubt very much that the sheet in question would have been so brittle, if it had not from a certain reason obtained its coarse grain.

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truth, and papers like this, coming from an entirely independent man, came with authority. Bearing this in mind therefore, he would like to call special attention to what was really the outcome from a practical point of view of Mr. Stead's researches.

He thought that, together with what evidence had gone before, it would now be freely admitted:

(1) That structure alone had such a powerful influence as to be fully able to produce brittleness, even with exceptionally pure material.

(2) That the best temperature from which material should be allowed to cool, in order to yield heterogeneous structure, was about 900° C., from which temperature it should cool fairly rapidly, say "naturally," as in the open air.*

(3) That, as in the other matters, so with annealing, one can have too much of a good thing.

(4) That the peculiar form of brittleness specially described in this paper, which might be termed "rectangular brittleness," was essentially a production of the user *not* the maker.

It would be remembered that in the writer's own paper on "Brittleness in Soft Steel," given in May last, in which he had dealt with four types of brittleness, two well known and two less recognised, much of the same ground was covered, and many of the same conclusions arrived at, although Mr. Stead and himself had been approaching the subject from opposite ends. Mr. Stead had, in the first place, by micro-examination of the brittle and rolled sheets, deduced what had taken place. He himself had, by two distinct types of treatment, under *known* conditions, synthetically produced, in the softest and purest steel made by well-known firms by various processes, brittleness which exactly resembled and was probably identical with two distinct types met with in actual experience, of which samples were shown.

In both the naturally and artificially produced samples the brittleness was removed and toughness completely restored by the same means as Mr. Stead found answer with rectangular brittle-

* This confirmed what the writer had said in his paper, both as to restoring toughness by heating to "cherry redness," and as to continuing work "down to red heat, but not to blue heat." In fact they wanted to keep between the two extremes, say, 1000 and 750° C.

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Mr. Stead said, "these changes are not effected rapidly, time is an important factor," but this it should be clearly understood referred only to granular development between 600° and 750° C., as at the higher temperatures, as shown above, the same changes took place quickly.

Mr. Stead had shown that the "rectangular brittleness" which he had specially described, was due to intercrystalline weakness, and the writer trusted he would not be regarded as in any way implying that the investigation of this kind of brittleness was of minor importance, if he suggested that it might prove that this was *not a distinct type* of brittleness, but only *a particular form*, which it assumed in plates or sheets, but produced by the same forces which produced the two types of brittleness he had himself described.

Indeed he had found identically the same treatment did produce quite different effects in different sections; as one instance of which he might refer to sample No. 42, which was ⅝-inch diameter round rod, and sample No. 43, which was part of a test-piece of ½-inch plate (both shown on Plate VI. of his own paper), which were both suspended side by side for the *same* length of time in the *same* ingot furnace, but No. 43 broke far more easily and showed a much coarser fracture than No. 42.

It was a question to him, however, whether *oxygen* * did not play a part in a good many cases, at least in the production of large grains and brittleness, both intergranular and intercrystalline, whether the molecular or granular structure was symmetrical or not, in short that (excluding shock at blue heat), there were three factors: Time × Temperature × Oxygen, and he should like to ask Mr. Stead whether he had tried the effect of heating for forty-eight hours to from 600° to 750° C., when the absence of oxygen was absolutely assured.

For his own part, in all the experiments he had made in the production of brittleness accompanied by large grains, oxygen had been present, except perhaps in the case of Experiment 39, where a rod was heated five minutes in cupola slag, and of 40, where it was heated twenty seconds in molten steel; also to

* Throughout he did not refer necessarily to oxygen *per se*, but to it by whatever medium conveyed.

being along the two outside edges of large grains of ferrite, the grains in the inner portion being very much smaller.

In a sample of wire, too, which showed a streak of red-shortness up one portion of the circumference corresponding to one corner of the billet from which it had been rolled, and which had evidently been burnt, thus proving that oxygen had been at work, there was a large V-shaped segment of ferrite extending inward almost to the centre.

These were only a few of the instances that could be quoted. Indeed it became a question whether in soft steel consisting as it did almost wholly of ferrite, and hence depending far more for its strength or weakness upon its structure, *i.e.* size and arrangement of grains, than upon its composition (considering the narrow limits within which this varied), annealing for a long period in the manner practised was beneficial. It was all very well for hard steel where it was necessary to give time to form laminated perlite structure. In all the brittle specimens the writer quoted in his paper, toughness was completely restored by heating for a moment to cherry redness, and either chilling in water or allowing to cool rapidly in the air.

Treatment similar to this, Mr. Stead said, completely removed brittleness. Might not some such treatment with rapid heating suffice and save the expense of annealing pots, &c.? There was no doubt that not only rapid cooling but rapid heating gave smaller grains, *vide* in his own paper billet Nos. 29 and 31, which had been heated up rapidly, viz. in quarter of an hour, as compared with No. 23. Thus by very *rapid heating* of the sheets singly or only a few at a time, the other necessary conditions, such as avoidance of heavy scale, &c., might be complied with and yet the desired effect obtained.

As regarded the suggestion in the latter part of Mr. Stead's paper, rerolling sheets at an angle of 15 degrees, to which Mr. Stead himself saw objections, many other ways might occur of producing the same effect, viz. a sheet in which the flow was not symmetrically disposed along straight lines, such for instance as by forming, tapering, hemispherical, or other suitably shaped projections of the nature of ragging upon the slab, so that the rolling down of these portions would give a curved or irregular flow.

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not to obtrude those opinions on them, besides he feared he had already exceeded the length of ordinary discussion.

Mr. STEAD, in reply, sent the following communication:—

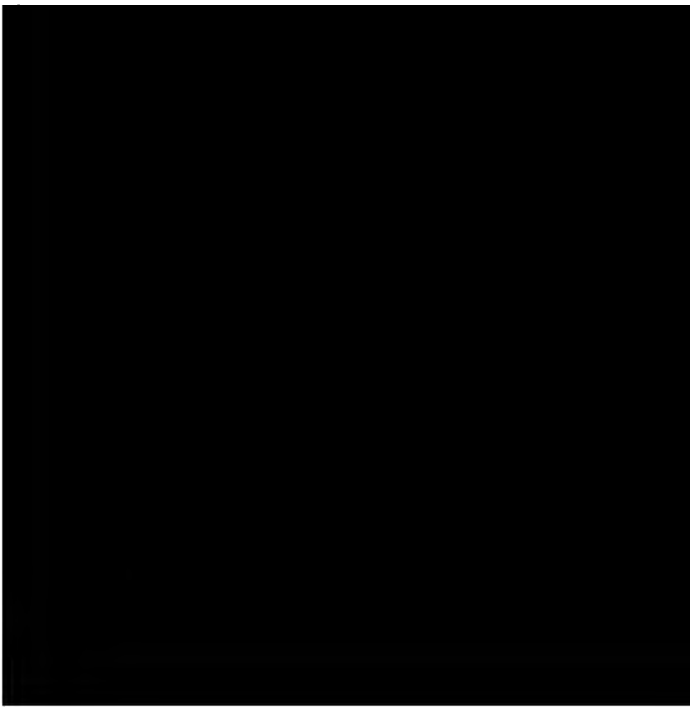
In answer to the objections by Professor Bauerman, Professor Arnold, and Mr. M'William to the term *grain* as a substitute for crystal in describing granular substances, he would only say that before writing his paper he had consulted various mineralogical works, and had used, he believed, some of the terms of mineralogists, at least the terms given in their books, and in this he had acted according to the advice of Professor Bauerman.

It was believed by some that the grains in iron were really true crystals, and that if they could be separated completely from each other and properly measured they would be found to have some of the angles and faces of true crystals; but the results of most careful measurement, and the examinations of sections, have led to the positive conclusion that they have no crystalline form, and that if they were separated and laid side by side, they would without exception be called *grains* by every metallurgist and mineralogist in existence. Why on the face of such acknowledged facts can objection be taken to their being called *grains* when they adhere together and form a compact mass as they do in iron?

Mineralogists' terms are clear enough in their books, for on referring to them we find that Professor Bauerman says that "Quartzite and statuary marbles, for instance, are aggregates of particles of quartz and calcite into masses of a slaty or *granular* texture, in which their proper forms are entirely lost." If we interpret a particle to be the same thing as a grain we may fairly claim that the terms applied to these rocks justify us in also calling the particles grains in the "rock iron," in which the proper form of the crystal is entirely lost. Every particle and grain in quartzite and marble is crystalline, but the particles are granular and justifiably called granular by mineralogists.

In the "Elements of Mineralogy," James Nichol (Professor of Natural History in the University of Aberdeen), on page 49, says:—

"Crystals have often been produced under conditions preventing the free development of their forms. They then compose



even grained holocrystalline rocks." The rocks are generally medium or rather *coarse grained.*

Throughout the whole of this most valuable little work we find repeated over and over again, in describing the structure of different rocks, the terms fine grained, coarse grained, and in the majority of cases the terms are applied to crystalline grains.

Judging from all these authorities we are bound to conclude that mineralogists clearly mean that if the crystalline particles in a holocrystalline rock have no regular form, these forms should be called grains, and not crystals. It was after the prolonged study of the structure of the particles differently oriented in iron which led him to the belief and conviction that it would be better to use the mineralogical terms of mineralogists, exactly in conformity with the advice given by Professor Bauerman at Stockholm.

Let us now refer to the nomenclature used by the leading metallographers, Professor Arnold and Mr. Andrew excepted.

Professor Martens, in his excellent paper on the Microstructure of Ingot Iron in Cast Ingots, Chicago Meeting, August 1893, continually uses the terms *grain* and *granular.* Mr. Osmond had already been quoted in the paper. Mr. Charpy, in his papers on the microstructure of alloys, also uses the term *grain.* Mr. Sauveur in his paper on Microstructure of Steel, Chicago Meeting, 1893, always uses the term *grain* and not *crystalline grain.* Mr. Howe is evidently in accord with other metallographers, for in a paper published in the *Engineering and Mining Journal* (Dec. 7, 1895), page 537, he, in conjunction with Mr. Sauveur, uses the term *grain* instead of the less expressive term *crystal.*

Practically the bulk of grains referred to in mineralogical works are crystalline, and the term *grain* — unless qualified by some such term as oolitic, &c.—may rightly be understood to be a crystalline grain. All metals are crystalline, and the grains must also be and are crystalline, but they are not crystals according to the mineralogists' definition. We may be and are quite justified in calling them grains without qualification; a qualification would only be needed if in any exceptional case they were found not to be crystalline.

Professor Arnold's definition of a grain as being a series of rounded bodies surrounded by a cement, does not appear to be in

[redacted]

[redacted]

formed by the junction of three edges, and it may be a cube, an octahedron, a rhomboid, or a tetrahedron, &c.

The statement then holds good that the equilateral triangles seen in martensite are not absolute proof of the presence of octahedrons or cubes.

The terminal angles and faces of crystals are really wanted for careful measurement. Professor Bauerman suggests that we should get well-formed crystals and measure the angles. That is excellent advice—get them, but when we remember that since Professor Bauerman and other mineralogists before him first commenced the study of the structure of iron, they have never got them. Get them by all means if you can, but do not throw cold water on the efforts of those who endeavour to get at the truth without having to wait perhaps for untold generations for the big things to turn up.

In his book Professor Bauerman states that iron crystallises in the cubic system, and every text-book on iron has the same statement. If every one of the authorities who have studied the question and written upon the matter in the past are wrong, then he, Mr. Stead, congratulated himself he was in good company, if he was also wrong. He claimed, however, contrary to Professor Bauerman's contention, that if the six sides of a closed geometrical solid obtained by cleavage developed perfectly square figures on etching, as he had shown was the case with iron, such evidence must be considered of value, and some proof of the solid being a cube or part of a cube.

The statement of Professor Arnold that he (the author) seemed to have based his conclusions about allotropic condition on the relative size of the grain in the three states is not consistent with what was stated. Nothing of the kind was suggested, neither had he suggested that iron quenched from above 900° to 750° were in the beta and gamma condition when cold.

The hypothesis that the thermal arrest (Ar2) is due to the crystallisation of iron has been exploded in the paper by the observation that the change was proved to take place in carbonless silicon steel, an observation which Professor Roberts-Austen was kind enough independently to confirm, and the change was unaccompanied by any alteration whatever in the crystalline structure. No notice was taken in the discussion of this im-

hardness of chilled steel is a function of the carbides diffused in the steel, the allotropists admit and do not dispute. Their position is, that the carbides in carbon steels, when quenched after heating, retain to a certain extent the allotropic states which are produced by heating. Although this hypothesis has not been proved beyond doubt, it is important that we should acknowledge the known proved facts upon which it is based.

The carbonists have no proof that the magnetic and thermal changes at Ar2 are not allotropic; the evidence, if we accept Professor Roberts-Austen's definition of allotropy, is a proof of allotropy.

The same remarks apply to the change in electric conductivity, the thermal change, and lastly the marvellous structural revolution which the author has shown takes place at the higher point Ac3.

All the evidence appears to point to the iron being different allotropically between 750° and 900° C., to what it is at when cooled slowly to under 700° C.

The question as to whether or not these allotropic changes are retained by the influence of carbon or carbon plus nickel and manganese, has not been discussed in the papers of the writer.

He considered that the two opposing parties were now so nearly in accord, they might now lay down the axe and join hands in the search for the missing links. Both the carbides and allotropy may have equally important functions, and to discuss as to which should hold the most important position reminds us of the discussion of the organist and the blower as to who was responsible for the music. No doubt each party will believe they are the musicians; the allotropists because they rightly claim that the allotropic changes take place independently of the carbon, and the carbonists with equal right that the intense hardness cannot be obtained without the carbon.

He (Mr. Stead) welcomed truth from whatever source it came, and had repeatedly maintained that the proper understanding of hardening would only be arrived at after much investigation. Believing a thing did not make it true, and he would suggest that we should bear that in mind.

In answer to Mr. Snelus' query, as to whether zinc is not responsible for the development of brittleness, it cannot be said

carbon, which was located in a large number of microscopic pearlite areas at the joints of the grains, had in the annealed specimens diffused, breaking up the structure of the large grains as far as it had penetrated into the grains, but in many cases leaving their central portions unaltered. On breaking the polished and etched specimens of the brittle material, fracture passed through the grains; the junctions appeared to be fairly strong.

Judging from the fact that carbonless coarse structured iron is broken up into finer grains by heating to a little above the point Ac3 900° C., and that the same breaking up occurs at lower temperatures in presence of carbon, it would almost lead us to believe that a change to gamma iron occurs, and that the formation of this gamma iron is coincident with the breaking up or refining of the grain.

It is not suggested that because gamma iron may be formed at 760° or 900° C. it necessarily remains gamma iron when cooled to 15° C.

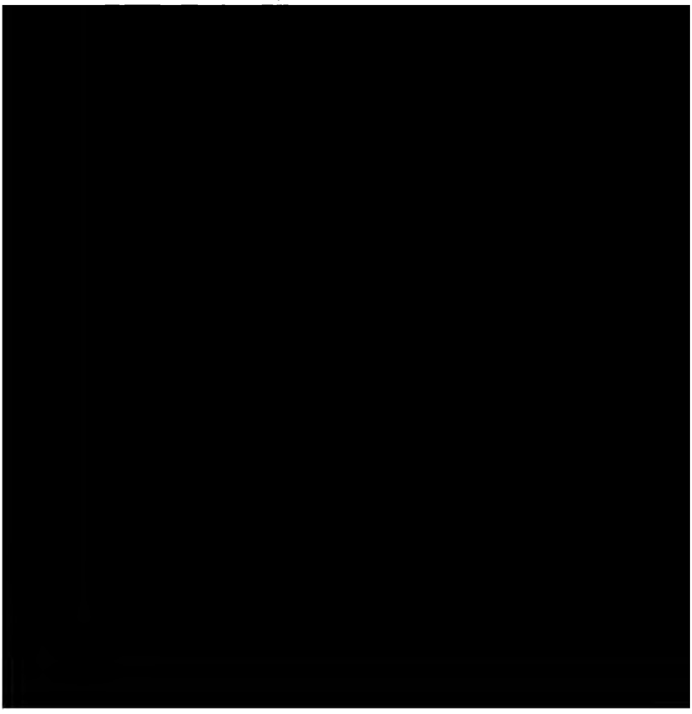
The conclusion formed at Stockholm that very soft steel was best annealed by heating for a short time at a high initial temperature was in accordance with the results given in his paper.

Mr. Ridsdale discusses the question from a practical standpoint, and suggests that the form of the rolls might be so altered as to cause the steel to flow in other than exactly straight lines when being reduced in thickness. We shall all be glad if Mr. Ridsdale develops his suggestion into a practical form so that a trial could be made. He suggests that oxygen may be responsible for the development of coarse granular structure. It may have something to do with it, and we shall be very glad to receive from Mr. Ridsdale experimental evidence to prove it.

It should be pointed out, however, that soft steel becomes coarse grained on cooling down in a slag ball out of contact with oxygen. We know very little, and much work is yet required to be done before we get at the truth.

Mr. E. H. Saniter sent the following reply to the discussion:

I cannot see what objection there is to the application of the word "grain" to the irregular subdivisions of a mass of steel.

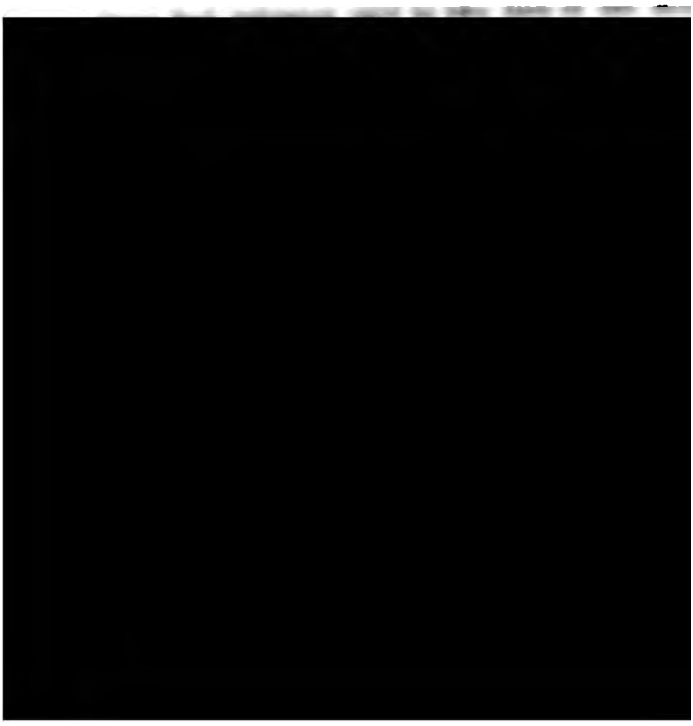


It appears to me that the balance of evidence is against the rhombic figures being sections of cubes. We know that normal iron exists as cubes, and that these are disclosed as cubes on etching, and I fail to see why we should distrust similar evidence in another case.

The PRESIDENT said they had seldom had a more interesting paper, and Mr. Stead deserved their warmest thanks.

A cordial vote of thanks having been passed to Mr. Stead,

The PRESIDENT called upon Professor Arnold to read his paper on the "Micro-Chemistry of Cementation."

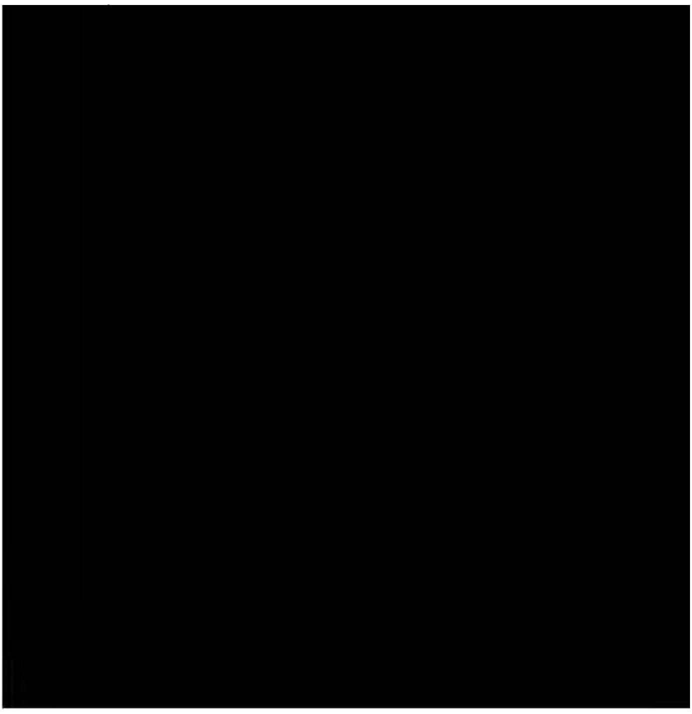


Practical Details of Cementation.

The furnace in which the bars herein described were converted contains two pots, each holding about 13 tons of steel. The average quantity of charcoal used per heat was about 200 bushels; the quantity of special coal consumed being about 15 tons per heat. The arch, which is turned over the bars and charcoal to make the stone pots or chests air-tight, is about 6 inches thick, being composed of "wheel-swarf," made by steel grinders, and consisting of silica from the stone mixed with rust and particles of free iron. On heating, this material becomes dense, and owing to a further oxidation of the involved steel particles it slightly expands, and hence does not readily crack. For mild heats the furnace is fired for about eight days, for medium heats about 9½ days, and for hard heats about eleven days. After firing the furnace is banked up, and the crucible is allowed to cool down during a period of about fourteen days. For a portion of the period last named the conversion is still actively proceeding, because the mass having to cool from an initial temperature of about 1000° C., necessarily remains for some time at a full red heat.

Classification of Cemented Bars.

Cemented bars are usually classed in six grades, namely, Nos. 2, 3, 4, 5, 6, and "glazed" or doubly converted bar, which might be called No. 7. The advent of mild steel, manufactured by the open-hearth and Bessemer processes, has rendered No. 1 bar practically obsolete. It probably contained little more than 0·3 per cent. of mean carbon, and on account of its mildness was known as "Irish temper." The bars are sorted by eye, a process demanding intuitive skill and no little experience. In dealing with cemented bar the carbon colour test is of very limited value, so far as every-day work is concerned, at any rate in the lower numbers, in the different layers of which the carbon varies greatly. Indeed in this matter, the practical "rule-of-thumb" man has more than held his own against the invading march of the analytical chemist. Mild converted bars are easily recognised from the fact that their centres contain a core of "sap," that is, practically unchanged iron. On the other hand,



the involved slag "fibres," which in the longitudinal section would of course appear as elongated streaks.

No. 2 *Bar.*—The 3 inch by ½ inch bar, after cleaning from scale, was sampled from the outside to the centre in twelve cuts taken on the planing machine. Each sample thus contained a layer of about 0·02 inch in thickness. The approximate mean carbon in each layer is tabulated below (Table I.), and its distribution is shown graphically in Fig. 1. The co-ordinates of this curve are depths in inches and carbons in percentage, the observed points being placed in the centre of each layer. (In this curve for the sake of uniformity the points are the mean of two observations at 0·2 inches apart, and are hence placed 0·04 inches apart.)

TABLE I. (No. 2 BAR).

Cut No.	Depth into Bar in Inches.	Mean Carbon per Cent.
1 (outside)	0·02	0·98
2	0·04	0·95
3	0·06	0·76
4	0·08	0·63
5	0·10	0·50
6 (median)	0·12	0·39
7	0·14	0·37
8	0·16	0·31
9	0·18	0·18
10	0·20	0·15
11	0·22	0·10
12 (centre)	0·24	0·10

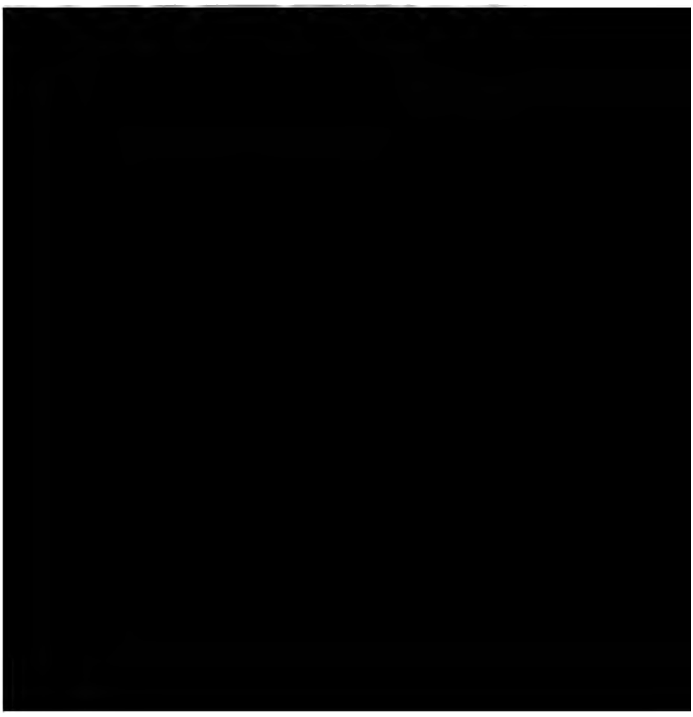
Mean carbon in half bar, 0·45 per cent.

Note.—This bar is rather milder than an average No. 2.

The varying micro-structure of No. 2 bar is well exemplified in sections 2, 3, and 4. These sections have not been etched with acid, their structures being very clearly thrown up by the action of the rouge and kid-skin employed for the last polishing process, which tints the ferrite blue,* leaving the cementite brilliant white and slightly in relief.

Section 2 consists of ferrite (the middle tone), dark slag dots, and a single patch of pearlite surrounded by thick, irregular walls of white cementite.

* This process does not develop the junctions between the crystalline grains of iron.



Section 6 shows the junction of the layer last named with the saturated steel forming the central layer of the bar and consisting of irregular polygons of pearlite, the junctions of which are however by no means distinct.

No. 4 Bar.—The sampling of this bar was carried out exactly as in the case of No. 3 Bar. The carbon results are contained in Table III., and are graphically plotted in Fig. 3.

TABLE III. (No. 4 BAR).

Cut No.	Depth into Bar in Inches.	Mean Carbon per Cent.
1 (outside)	0·04	1·50
2	0·08	1·45
3	0·12	1·27
4	0·16	1·29
5	0·20	1·29
6 (centre)	0·24	1·15
Mean carbon in half-bar, 1·33 per cent.		

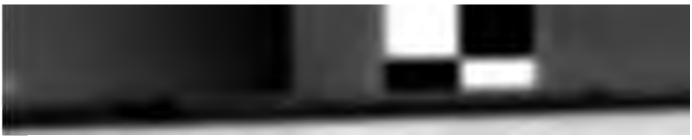
Section 6 is from the outside of the bar, and presents a greyish stippled background of normal pearlite in which the surplus cementite occurs in very varying forms; in some areas as heavy streaks, in others as remarkably regular laminæ. The centre of the bar has not been figured from lack of time. It shows a supersaturated steel in which the cementite is not well meshed, but has segregated into irregular streaks.

No. 5 Bar.—This was of fairly uniform carbon throughout, the mean percentage being nearly 1·6.

Its typical structure is shown in Section 7. It consists of large pearlite polygons enveloped in somewhat thick membranes of cementite, a considerable amount of the latter also appearing in streaks and laminæ in the interior of the polygons.

No. 6 Bar.—This also was of almost uniform carbon throughout, the mean percentage being about 1·8.

Section 8 shows the micro-structure characteristic of No. 6 bar. The constituents are identical with those described for Section 7. The quantity of cementite present is, however, of course considerably greater, and it seldom presents such a perfect sectional mesh-work as that characteristic of No. 5 Bar.



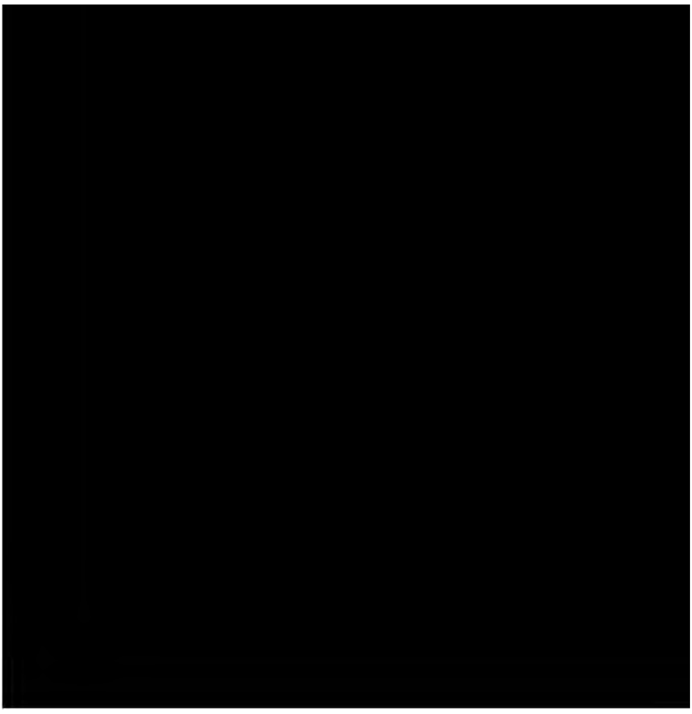


TABLE IV. (No. 4 BAR AFTER "AIRING").

Cut No.	Depth into Bar in Inches.	Mean Carbon per Cent.
1 (outside)	0·02	0·00
2	0·04	0·00
3	0·06	0·30
4	0·08	1·20
5	0·10	1·45
6	0·12	1·45
7	0·14	1·45
8	0·16	1·40
9	0·18	1·38
10	0·20	1·38
11	0·22	1·35
12 (centre)	0·24	1·16
Mean carbon in half-bar, 1·04 per cent.		

Section 11 shows the abrupt junction of the decarbonised outer layer of the aired bar with the hard steel lying about one-tenth of an inch below the surface. The median layer presents the usual structure of well-supersaturated steel. The outer layer, however, consists of ferrite mixed with streaks and dots of oxide of iron. The crystalline joints of the iron do not appear because of the light etching to which the sample was subjected in order not to obscure the structure of the pearlite in the carbonised region by over-etching. On deeply etching, the ferrite developed junctions bounding large crystalline grains, some of them being cemented together with oxide of iron. These crystals were of that columnar and radial form described by Mr. Stead in his paper on "The Crystalline Structure of Iron and Steel," thus confirming his results as to the peculiar structure of decarbonised surfaces.

The general results obtained during the present investigation are set forth in Table V.

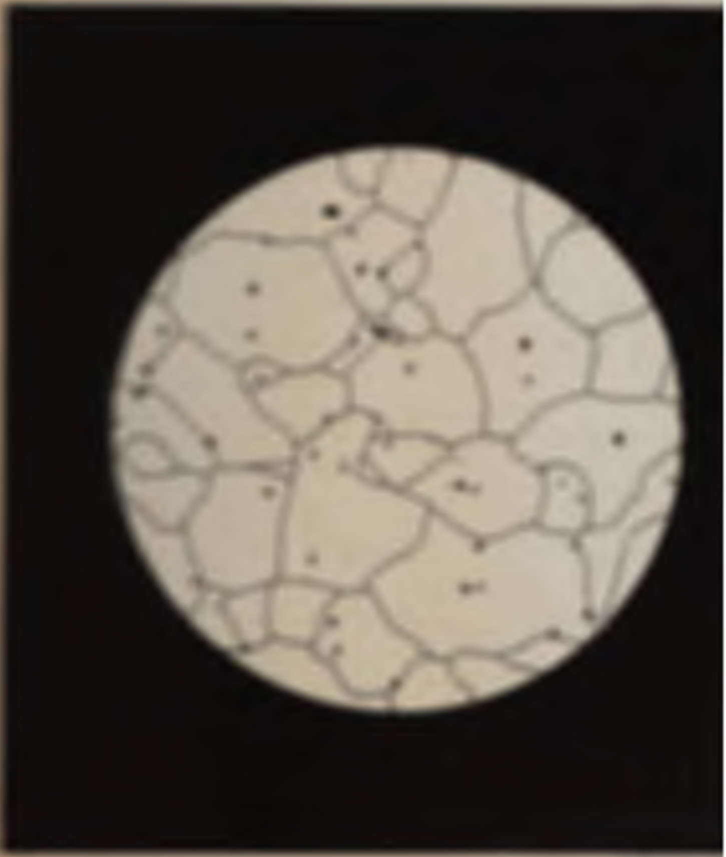
TABLE V.

Material.	Mean Carbon per Cent.	Remarks.
Bar iron	0·05	Fairly uniform throughout.
No. 2 bar *	0·45	Three distinct layers.
No. 3 bar *	1·13	Three distinct layers.
No. 4 bar *	1·33	Two distinct layers.
No. 5 bar	1·60	Practically uniform.
No. 6 bar	1·80	Practically uniform.
Glazed bar	1·90	Fairly uniform.
Aired bar	1·04	Three distinct layers.

* The true mean carbons in bars Nos. 2, 3, and 4, will be rather higher than those tabulated, owing to the cementation proceeding *via* the *edges* of the bars, from which the carbon penetrates in directions at right angles to those of the main conversions proceeding *via* the flat surfaces of the bars.

PLA

SECTION 1.



Transverse section of Swedish Lancash
Hearth Bar Iron.

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Plate XII.

Section 2

No. 2 Bar (Unetched). Centre of Bar.

[illegible]

[illegible]

Plate XIII.

Section 3.

Plate XIV.

SECTION 4.

SECTION 5.

FIG. 2 BAR (ETCHED). OUTER AND MEDIAN LAYERS.

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Plate XVII.

Section 7.

[illegible]

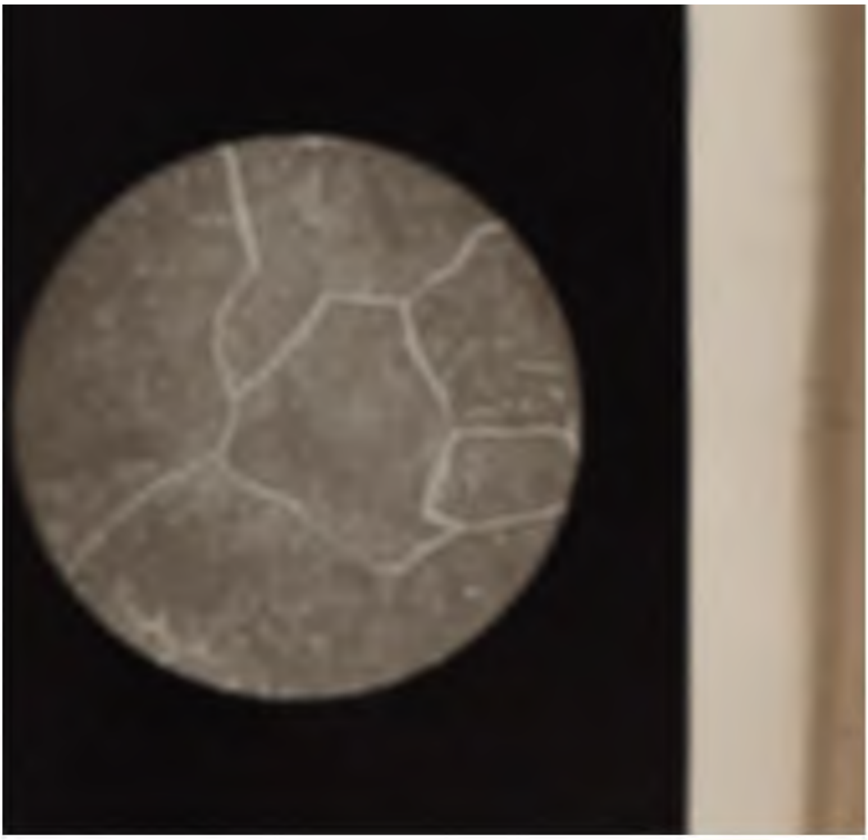

PLATE XIX.

SECTION 9.

FIG. 9 BAR (ETCHED). STRUCTURE UNIFORM THROUGHOUT.

[illegible]

[illegible]

Plate XXI.

Section 11.

[illegible] Bar showing Decarburized Outer Layer and Supersaturated Region beyond.

[illegible] 2.10 & 1.40 respectively. Magnified 96 Diameters.

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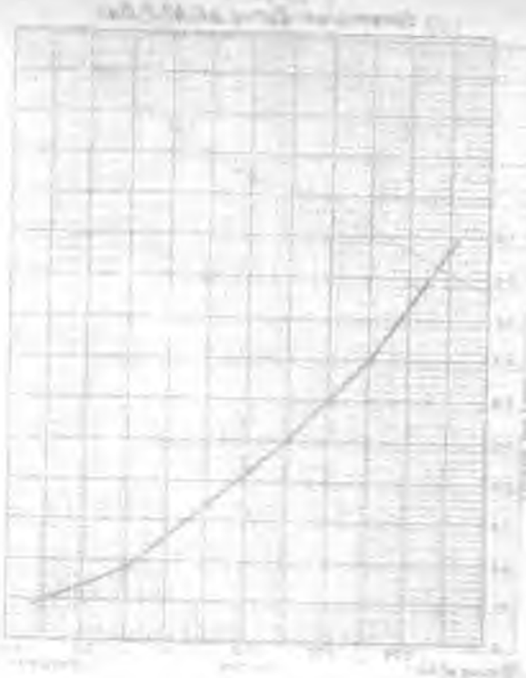

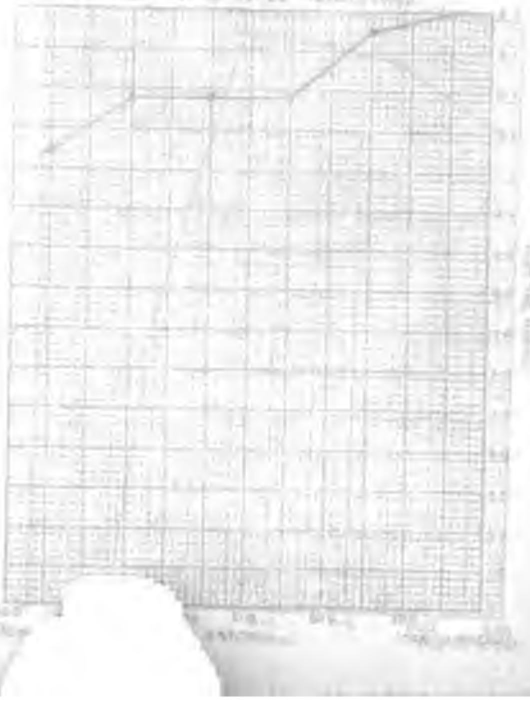

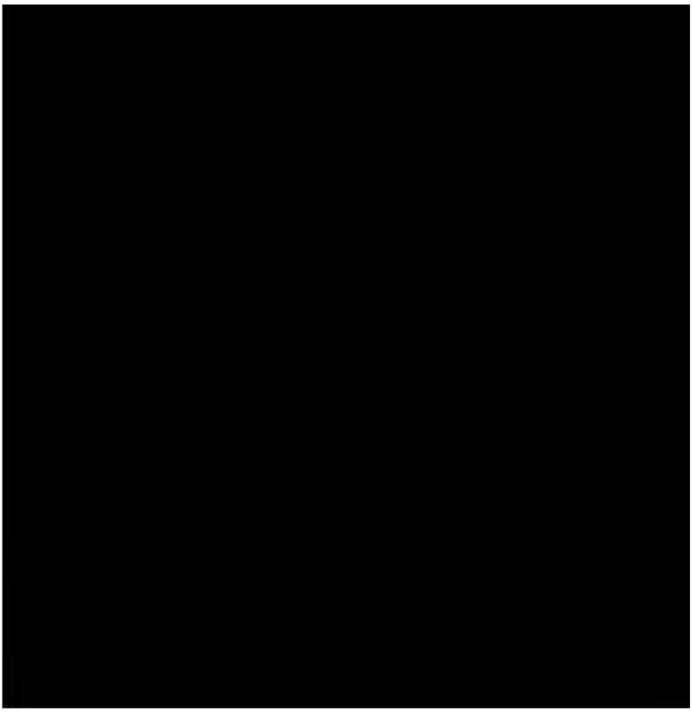

Some of these provisional conclusions have been strengthened by remarkable results communicated to the author by Mr. B. W. Winder, F.R.M.S., of the Continental Steel Works, Sheffield. He found that small bars could be cemented up to the saturation-point very quickly, but that afterwards supersaturation proceeded at the rate of only about 0·05 per cent. of carbon per day.

Arnold; his contention, as opposed to Professor Arnold's view, being that the fact that at a definite temperature iron is saturated by 0·9 per cent. of carbon, does not afford the slightest evidence of the existence of the supposed compound $Fe_{24}C$.

Mr. A. GREINER, Member of Council, said it was just a year ago at the Congress in that same room he had called attention to the resistance of materials, and they had the pleasure of hearing a lecture by Mr. Osmond, who was well known as being one of the most celebrated men on microscopic questions. Mr. Osmond showed them very interesting diagrams illustrating the trials he had made of several alloys, and especially the alloys of iron and steel. As a practical man, he must say that he was glad to think that science was going more and more into the details of the making of steel; and ironmakers did not fear at all that science would trouble their management of works. They thought that science would throw light upon such facts as they met with every day in their practice; and he was always thankful for the aid of science in their industry.

Professor ARNOLD said he had only one or two words to say in reply to Professor Roberts-Austen. He thought that practically they were perfectly in agreement. From a large number of experiments he had made he was perfectly convinced that there were two distinct varieties of interpenetration taking place at different temperatures. When the results were published he felt sure that Professor Roberts-Austen would feel it necessary to modify his views that the question of chemical formulæ was wholly inadmissible. He could only thank the Institute for the beautiful way in which the illustrations in his paper were produced, and for the interesting discussion they had had on it.

CORRESPONDENCE.

Mr. J. E. STEAD, Member of Council, said he had very great pleasure in complimenting Professor Arnold upon the accuracy of his observations and the perfection of his illustrations. He (Mr. Stead) had examined practically all the classes of cement

[illegible] by Professor Arnold. The results, however, on [illegible] homogeneous [illegible] to the cementation pro[illegible] [illegible] had [illegible], especially in the case of the [illegible] per cent. [illegible] a little different from that given by Professor Arnold; [illegible] structure was practically [illegible] from any massive cementite; [illegible] consisted of very regular pearlite, and gave the most magnifi[illegible] pearly structure and play of colours of any samples that he [illegible] examined. The difference in the two structures was [illegible] due to the more homogeneous character of the welded iron [illegible] with the bars experimented upon by Professor Arnold. [illegible] Mr. Stead's observations upon annealed steels proved [illegible] enough that the carbide Fe_3C tended to fall together and [illegible] in large masses, occupying in such steels compound [illegible] of pearlite. The drawings of Professor Arnold are [illegible] of this, for wherever a thick layer of cementite is formed [illegible] that band had evidently become a centre of attraction, [illegible] the carbide tended to fall into or coalesce with this mass. [illegible] segregated mass of cementite represents a centre of greater [illegible], and if that centre becomes more and more massive [illegible] the attraction becomes greater, and the result is that [illegible]

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shown, and if they had been cooled rapidly at such a time, would have been fixed in these extended areas; but as the external laminæ of Fe_3C were separated by masses of ferrite the attraction of the outer bands of cementite would be towards the centre of the areas, with the result that they coalesced and formed thick envelopes. When the patches of pearlite and carbon were very small, all the laminæ of the pearlite fell together to form separate masses of cementite. This was shown in his (Mr. Stead's) paper on "The Crystalline Structure of Iron."

It would be most interesting if it could be ascertained by experiment whether or not, by very prolonged annealing at a temperature of 650° C., or just below that point, a complete coalescence of the carbide in the pearlite in steels containing from two to three tenths per cent. of carbon could be obtained. On the face of the results before us, we should imagine that if the conditions were right, such steels would eventually be obtained containing nothing but ferrite and masses of cementite, with no pearlite whatever.

Professor Arnold says that massive cementite is obtained on annealing at 650°, but he does not say what carbon the steels experimented with contained. Would he kindly give us these carbons?

Professor ARNOLD stated, in reply to the most valuable remarks of Mr. Stead, that he also had found that saturated steels were little liable to form massive cementite. Nevertheless small masses were sometimes produced on annealing even hammered and rolled bars from steel ingots just on the saturation point.

With reference to semi-saturated steels (about 0·45 per cent. C.) the author had never observed the coarse pearlite areas completely enveloped in cementite, his experience being rather that the envelopment is only partial, so that the striæ in the cells are dovetailed into the ferrite outside to a very considerable extent. If Mr. Stead would again closely examine the micrograph of the median section of No. 2 bar he would find such to be the case there. The author had found the massing of the cementite striæ most marked in the pearlite areas of mild steels, *e.g.*, about 0·15 per cent. C. In the experiments made by the author it was doubt-

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THE ACTION OF METALLOIDS ON CAST IRON.

By GUY R. JOHNSON, Embreville, Tennessee.

In presenting to the Institute the following paper, written at the suggestion of one of its prominent members, the writer wishes to say at the outset that it has been prepared from an American foundryman's standpoint, and that while it differs, in all probability, much from the standpoint of the British and Continental manufacturers, yet it is hoped that it may promote an interchange of views, without which no trade can hope for advancement.

Never in the history of manufacture has there been a time when saving was more necessary, and never a time when there was more need for scientific and practical men to come together on a firm basis of mutual understanding.

It is now almost entirely conceded, at least on this side of the Atlantic, that the successful management of a modern foundry embraces a knowledge of chemistry, and a proper understanding of the effects produced by the various metalloids on cast iron.

It is with a view to throwing some light on the vexed question of the chemistry *versus* the physics of cast iron that this paper is submitted. By its aid it is hoped that the foundryman who cannot afford the services of a chemist may yet be enabled to buy his iron understandingly. The tests and analyses presented have been extended over nearly three years' time, and are in many cases the mean of a number of tests or analyses. Much of it has appeared in print before, especially the tables, which were printed in full in some of the American technical papers in 1897. It should be said, however, that all of the data from which the tables were prepared have been checked up, and the results found so concordant that it has not been deemed necessary to change them from their original form.

The value of the subjoined notes is necessarily weakened in some degree by the fact that only one iron—viz., Embreville—

Another coke analysis, same furnace, but nearer in silicon to the charcoal analysis, is :—

Silicon	1·38
Sulphur	0·044
Phosphorus	0·361
Manganese	0·55

Carbons not determined, but not far different from the first. The result of four bars was 26,240 lbs.

Analysis of the carbon figures is instructive—

	Carbon in Charcoal Iron.	Carbon in Coke Iron.
Graphitic	2·32	3·02
Combined	0·89	0·75
Total	3·21	3·77

Percentage combined carbon to graphitic—

Charcoal iron	27·7 per cent.
Coke iron	20·0 ,,

In other words, charcoal iron is stronger than coke iron, because it contains less carbon, and its combined carbon is higher in proportion to the graphitic than is the case in the coke iron.

To still further check this theory, the author has tried the experiment of melting wrought scrap with pig iron in the cupola in order to attain a lower resultant carbon.

As it is a well-known fact among foundrymen that castings produced in this way are spongy and unreliable, the mixture was run into pigs and then re-melted; this gave a homogeneous iron of great strength, as the accompanying analysis and tensile strength show :—

Silicon	0·94
Sulphur	0·037
Phosphorus	0·192
Manganese	0·21
Graphitic carbon	2·58
Combined carbon	0·46

Tensile strength of bar turned from the centre of a full-sized pig, 34,010 lbs.

This experiment was repeated many times, varying the proportion of wrought scrap each time, but the results in each

foundry, combined with the chilling of the sand mould, generally produces the desired grain; while by using metal chills and sufficiently low silicon contents, all of the graphitic carbon will be changed to combined carbon, giving a white iron. Sufficient repetition of re-melting, with the consequent loss of silicon, will make a perfectly grey iron white. In malleable work an air furnace is used to produce this effect on the first melt, though in this class of work the process is carried further, and more of the carbon is burned off.

Silicon.—The effect of this element on cast iron is probably better known than any other occurring therein. Its proportion varies all the way from a small fraction of 1 per cent., as in white and basic open-hearth irons, to 17 per cent. or over in ferro-silicons. Its influence on foundry irons is that of a softener, *i.e.*, it tends to turn the carbon in the iron into the graphitic state. Just what its influence *per se* on iron is it is impossible to say, owing to its great power over carbon, from which it is impossible to disassociate it. It is probable that its effect is to weaken, but with the ordinary run of carbons up to $1\frac{1}{2}$ per cent. seems to make little difference, although it will be observed that the strongest iron in the tables is the lowest in silicon. It will also be noticed that the sulphur is comparatively high, quite enough to transform much graphitic carbon into combined. (See Table III.)

Sulphur.—This element turns graphitic carbon into the combined state, and hence makes cast iron harder, denser, and more liable to crack. The hotter the iron the lower the sulphur, and hence the more graphitic carbon. From this it follows that Nos. 1 and 2 foundry have little sulphur, and it is a fact that they frequently contain less than 0·01 per cent., while a No. 3 or grey forge from the same furnace will frequently run well up towards 0·1 per cent., and white iron with over 0·3 per cent. is not unusual. Such iron is usually as brittle as glass. Owing, however, to the above-mentioned characteristic, that sulphur has a tendency to convert graphitic carbon into combined carbon, it is valuable in certain classes of foundry-work, and an iron to show great strength and density should contain from 0·05 to 0·075 per cent., or even higher, this being a point which can only be obtained by careful experiments on the iron being used. For

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runs about 1–1·25 per cent. The above also holds true for light thin castings, *i.e.*, they should be made of iron running high in phosphorus, 1–1·25 per cent., even higher, varying with the character of the casting. At the same time, it must be remembered that for work requiring high tensile strength, a low phosphorus iron is preferable. Such iron should probably not contain over 0·5 per cent.

Car-wheel iron runs still lower, 0·2 to 0·4. Iron containing less than 0·2 per cent. is, however, apt to shrink badly, and to run red and short. But it is suitable for making malleable castings of, and for mixing with other phosphorus irons to obtain a strong mixture. (See Table IV.)

Manganese.—Like sulphur, manganese has a strong tendency to convert graphitic carbon into combined carbon. Although it possesses the quality of enabling the iron to take up more carbon, as per the following analyses:—

	Embreville "Malleable Iron."	Embreville "High Manganese Iron."
Silicon	1·13	1·21
Sulphur	0·019	0·011
Phosphorus	0·185	0·185
Manganese	0·81	3·61
Graphite carbon	3·32	3·47
Combined carbon	0·80	0·97
Total carbon	4·12	4·44

As a general rule, it may be stated that the more manganese an iron contains, the more carbon it will carry.

Of course, being a "hardener," the ordinary foundryman does not like an iron containing much manganese, and the average pig produced in the United States contains from 0·50 to 0·75, so that not much attention is paid to this element—not as much as there should be, for owing to its affinity for sulphur it serves, in melting in the cupola, to carry off much of this element, which would otherwise combine with the iron, and it is well known to some foundrymen that a cupola iron loses its manganese by combination with sulphur, the sulphide passing off with the slag. Furthermore, the best "softeners" ever made, some of the Scotch brands, habitually run over 1 per cent., and this fact in itself is a sound reason for using higher manganese.

The presence of manganese is desirable in low silicon iron for

If a strong machinery casting is wanted, use an iron of close No. 3 to grey forge fracture, silicon from 0·80 to 1·50 per cent., sulphur from 0·03 to 0·05 per cent., phosphorus from 0·35 to 0·50 per cent.

For hydraulic cylinders, &c., use the same composition as above, but let the sulphur run from 0·075 to 0·110 per cent.

For chilled wheels the iron should analyse about as follows: Silicon 0·5 to 0·8 per cent., sulphur 0·02 to 0·04 per cent., manganese 1 per cent., fracture preferably No. 3 or close No. 2.

In this connection it ought to be stated that while silicon seems to be the governing element in chill iron (see Tables XII. and XIV.), at the same time phosphorus has its effect, as before noted, in changing graphitic carbon to combined carbon.

The difference, however, between the chill fracture of a low phosphorus iron and that of the same silicon high phosphorus iron is quite striking. In the low phosphorus iron the white or chilled part extends down into the grey portion of the castings like fingers, while in the high phosphorus iron the line between the chilled and grey parts is markedly straight (see Table No. XIV.). It is this interlacing that renders the low phosphorus iron so much more valuable for making car wheels, chilled rolls, &c.

One word ere the close of this paper on the subject of test bars. The controversy over the shape, size, and results given of test bars has raged for the past few years throughout the land.

If the views of the writer are correct, it would seem to indicate that the advocate of each size is correct, or incorrect, in direct proportion as the size of his test bar approximates that of the castings, especially in regard to thickness.

By many the ½-inch bar is condemned as giving too high results. This arises simply from the fact that, being small, the iron is quickly chilled, and the casting contains much combined carbon, thereby promoting its density and tensile strength. If, therefore, castings ½-inch thick are to be made, by all means use the ½-inch bar; preference in all cases being given to round bars as most apt to give regular results, owing to synchronous cooling, which cannot be present when there are four corners, at which the cooling must necessarily start.

The writer feels inclined to insist on the foundryman's re-

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TABLE I.—*Embreville Iron.*

Tensile strength. Silicon, sulphur, phosphorus constant. Carbons variable.

Series No.	Grade Melted.	Analysis Test Bars.						Physical Tests.		
		Silicon.	Sulphur.	Phosphorus.	Graphite.	Compound Carbon.	Grain after Melting.	Bar. R. Sq. Inch.	Breaking Strain.	Per Square Inch.
1	1 F.	1·20	0·066	0·175	3·72	0·15	Very open	¾	7,750	17,500
2	1 F.	1·24	0·053	0·179	3·65	0·20	Very open	¾	7,800	17,650
3	2 F.	1·29	0·067	0·170	3·50	0·28	Open bright	¾	9,850	22,300
4	2 F.	1·21	0·069	0·179	3·52	0·33	Open bright	¾	9,900	22,400
5	2 F.	1·28	0·057	0·171	3·49	0·35	Open bright	13-16	10,050	19,350
6	2 F.	1·27	0·063	0·175	3·58	0·32	Open bright	13-16	9,750	18,800
7	3 F.	1·20	0·068	0·175	3·45	0·39	Close bright	13-16	11,100	21,400
8	3 F.	1·20	0·066	0·170	3·42	0·40	Close bright	¾	10,850	24,550
9	G. F.	1·29	0·053	0·175	3·48	0·35	Grey	¾	10,650	24,100
10	G. F.	1·28	0·055	0·179	3·34	0·56	Grey	¾	13,200	29,850
11	G. F.	1·25	0·066	0·170	3·32	0·61	Grey	13-16	12,950	24,950
12	G. F.	1·25	0·067	0·170	2·88	0·98	Very close grey	13-16	17,450	33,650
13	G. F.	1·21	0·061	0·174	2·95	0·93	Very close grey	13-16	17,550	33,850
14	G. F.	1·29	0·053	0·179	2·84	0·92	Very close grey	¾	15,900	35,950

TABLE II.—*Embreville Iron.*

Tensile strength. Silicon, sulphur, carbons constant. Phosphorus variable.

Series No.	Grade Melted.	Analysis Test Bars.						Physical Tests.		
		Silicon.	Sulphur.	Phosphorus.	Graphite.	Compound Carbon.	Grain after Melting.	Bar. R. Sq. Inch.	Breaking Strain.	Per Square Inch.
1	G. F.	1·09	0·080	0·121	3·03	0·78	Grey	13-16	13,250	25,550
2	G. F.	1·10	0·072	0·143	3·10	0·79	Grey	13-16	12,900	24,950
3	G. F.	1·01	0·075	0·150	2·93	0·82	Grey	¾	12,700	28,750
4	G. F.	1·13	0·081	0·174	3·00	0·81	Grey	13-16	13,100	25,250
5	G. F.	1·08	0·076	0·208	2·89	0·88	Grey	13-16	12,900	24,850
6	G. F.	1·06	0·078	0·247	2·96	0·85	Close grey	¾	13,400	30,300
7	G. F.	1·11	0·083	0·303	3·02	0·75	Close grey	¾	13,350	30,200
8	G. F.	1·03	0·073	0·354	2·96	0·83	Close grey	13-16	11,900	22,950
9	G. F.	1·02	0·078	0·412	2·91	0·85	Light grey	¾	10,850	24,550
10	G. F.	1·09	0·081	0·453	2·83	0·80	Light grey	13-16	10,100	19,450
11	G. F.	1·07	0·073	0·517	2·80	0·88	Light grey	13-16	10,050	19,350
12	G. F.	1·07	0·082	0·554	2·83	0·81	Light grey	13-16	10,750	20,700

Table V.—*Embreville Iron.*

Transverse strength. Silicon, sulphur, phosphorus constant. Carbons variable.

Series No.	Grade Melted.	Analysis Test Bars.						Physical Tests.		
		Silicon.	Sulphur.	Phosphorus.	Graphite.	Combined Carbon.	Grain after Melting.	Bar. 24-Inch Centres. Inches.	Breaking Strain.	Deflection in 32nd Inches.
1	1 F.	1·20	0·066	0·175	3·72	0·15	Very open	1×2×26	1,750	9
2	1 F.	1·24	0·053	0·179	3·65	0·20	Very open	1×2×26	1,800	10
3	2 F.	1·29	0·067	0·170	3·50	0·28	Open bright	1×2×26	2,050	13
4	2 F.	1·21	0·069	0·179	3·52	0·33	Open bright	1×2×26	2,050	13
5	2 F.	1·28	0·057	0·171	3·49	0·35	Open bright	1×2×26	2,100	14
6	2 F.	1·27	0·063	0·175	3·58	0·32	Open bright	1×2×26	2,000	13
7	3 F.	1·20	0·068	0·175	3·45	0·39	Close bright	1×2×26	2,600	16
8	3 F.	1·20	0·066	0·170	3·42	0·40	Close bright	1×2×26	2,500	15
9	3 F.	1·29	0·053	0·175	3·48	0·35	Grey	1×2×26	2,600	16
10	G. F.	1·28	0·055	0·179	3·34	0·61	Grey	1×2×26	2,850	17
11	G. F.	1·25	0·066	0·170	3·32	0·56	Grey	1×2×26	2,950	17
12	G. F.	1·25	0·067	0·170	2·88	0·98	Very close grey	1×2×26	3,050	18
13	G. F.	1·21	0·061	0·174	2·95	0·93	Very close grey	1×2×26	3,100	19
14	G. F.	1·29	0·053	0·179	2·84	0·92	Very close grey	1×2×26	2,950	19

Table VI.—*Embreville Iron.*

Transverse strength. Silicon, sulphur, carbons constant. Phosphorus variable.

Series No.	Grade Melted.	Analysis Test Bars.						Physical Tests.		
		Silicon.	Sulphur.	Phosphorus.	Graphite.	Combined Carbon.	Grain after Melting.	Bars. 24-Inch Centres. Inches.	Breaking Strain.	Deflection.
1	G. F.	1·09	0·080	0·121	3·03	0·78	Grey	1×2×26	2,650	16
2	G. F.	1·10	0·072	0·143	3·10	0·79	Grey	1×2×26	2,700	17
3	G. F.	1·01	0·075	0·150	2·93	0·82	Grey	1×2×26	2,800	17
4	G. F.	1·13	0·081	0·174	3·00	0·81	Grey	1×2×26	2,600	17
5	G. F.	1·08	0·076	0·208	2·89	0·88	Grey	1×2×26	2,650	16
6	G. F.	1·06	0·078	0·247	2·96	0·85	Close grey	1×2×26	2,850	18
7	G. F.	1·11	0·083	0·303	3·02	0·75	Close grey	1×2×26	2,800	18
8	G. F.	1·03	0·073	0·354	2·96	0·83	Close grey	1×2×26	2,700	17
9	G. F.	1·02	0·078	0·412	2·91	0·85	Light grey	1×2×26	2,500	14
10	G. F.	1·09	0·081	0·453	2·83	0·80	Light grey	1×2×26	2,250	10
11	G. F.	1·07	0·073	0·517	2·80	0·88	Light grey	1×2×26	2,100	10
12	G. F.	1·09	0·082	0·554	2·83	0·81	Light grey	1×2×26	2,150	9

[illegible]

TABLE VIII.—[illegible] Iron.

[illegible] strength. Silicon, phosphorus, [illegible] constant. Sulphur variable.

[illegible]	Analyses Test Bars						Physical Tests		
	Silicon	Sulphur	Phosphorus	Graphite	Combined Carbon	Grain after Melting	Bar [illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TABLE IX.—[illegible] Iron.

[illegible] Phosphorus, sulphur, [illegible] constant. Silicon variable.

[illegible]	Analyses Test Bars						Physical Tests	
	Silicon	Sulphur	Phosphorus	Graphite	Combined Carbon	Grain after Melting	[illegible]	Number of [illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[redacted]

TABLE X.—*Embreville Iron.*

Drop tests. Silicon, sulphur, carbons constant. Phosphorus variable.

Series No.	Analysis Test Bars.						Physical Tests.	
	Silicon.	Sulphur.	Phosphorus.	Graphite.	Combined Carbon.	Grain after Melting.	Size bars 12-inch Centres. Inches.	Number of Blows.
1	1·01	0·075	0·150	2·93	0·82	Grey	1×1×15	11
2	1·08	0·076	0·208	2·89	0·88	Grey	1×1×15	10
3	1·11	0·083	0·303	3·02	0·75	Close grey	1×1×15	8
4	1·02	0·078	0·412	2·91	0·85	Close grey	1×1×15	3
5	1·07	0·073	0·517	2·80	0·88	Light grey	1×1×15	1

TABLE XI.—*Embreville Iron.*

Drop tests. Silicon, phosphorus, carbons constant. Sulphur variable.

Series No.	Analysis Test Bars.						Physical Tests.	
	Silicon.	Sulphur.	Phosphorus.	Graphite.	Combined Carbon.	Grain after Melting.	Size Bars. 12-inch Centres. Inches.	No. Blows.
1	1·19	0·072	0·197	3·07	0·80	Grey	1×1×15	10
2	1·23	0·141	0·202	2·96	0·77	Grey	1×1×15	8
3	1·26	0·172	0·207	3·09	0·82	Close grey	1×1×15	8

TABLE XII.—*Embreville Iron.*

Chilling test. Phosphorus, sulphur, carbons constant. Silicon variable.

Series No.	Analysis.			Physical Tests.	
	Silicon.	Sulphur.	Phosphorus.	Chilling Piece. Inches.	Depth of Chill.
1	1·76	0·067	0·179	1×2×20	Close but no chill
2	1·55	0·068	0·185	1×2×20	Perceptible at edge
3	1·27	0·070	0·178	1×2×20	$\frac{1}{8}$-inch thick
4	1·05	0·069	0·181	1×2×20	$\frac{1}{4}$-inch thick
5	0·88	0·065	0·183	1×2×20	$\frac{5}{8}$-inch thick
6	0·31	0·070	0·179	1×2×20	Entirely chilled

The chilling strip placed at the bottom. The bar chilled for 20 inches along the 1-inch face. Chill noted is the average of the bar. Analyses are from chilled pieces. Unchilled bars of above section are all grey.

TABLE XIV.—[illegible]

[illegible]

	Analysis				Physical Tests	
[illegible]	Silicon	Sulphur	Phosphorus	[illegible]	Size Bar Section	Depth of Chill Inch
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

TABLE XV.—[illegible]

[illegible]

[illegible]	Analysis before Melting			[illegible]	Analysis after Melting		
	Silicon	Sulphur	Phosphorus		Silicon	Sulphur	Phosphorus
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table XVI.—*Embreville Iron.*

Varying combinations in the same fracture and face.

Series No.	Cast No.	Silicon.	Sulphur.	Phos-phorus.	Fracture.	Face.
1	278	0·55	0·109	0·211	G. F.	Deeply pitted.
2	50	2·86	0·133	0·334	G. F.	Deeply pitted.
3	313	0·62	0·140	0·160	G. F.	Deeply pitted.
4	54	2·39	0·108	0·249	G. F.	Deeply pitted.
5	745	0·83	0·023	0·217	G. F.	Smooth.
6	366	1·22	0·016	0·243	G. F.	Smooth.
7	782	1·29	0·021	0·239	3 F.	Smooth.
8	523	2·28	0·071	0·167	3 F.	Deeply pitted.
9	364	1·36	0·012	0·347	3 F.	Smooth pitted.
10	821	1·88	0·011	0·227	3 F.	Smooth pitted.
11	99	0·41	0·027	0·169	3 F.	Smooth.
12	22	3·22	0·049	0·776	3 F.	Slightly pitted.
13	97	0·64	0·024	0·167	2 F.	Smooth.
14	119	0·76	0·021	0·151	2 F.	Smooth.
15	66	1·16	0·015	0·179	2 F.	Smooth.
16	123	1·57	0·016	0·268	2 F.	Smooth.
17	75	0·49	0·164	0·134	2 F.	Deeply pitted.
18	244	1·56	0·044	0·179	2 F.	Deeply pitted.
19	4	2·12	0·021	0·360	2 F.	Smooth.
20	7	2·97	0·027	0·432	2 F.	Smooth.
21	10	3·44	0·021	0·428	2 F.	Smooth.
22	96	0·71	0·019	0·165	2 F.	Smooth.
23	193	1·05	0·023	0·229	2 F.	Smooth.
24	36	1·63	0·026	0·177	2 F.	Smooth.
25	679	2·00	0·011	0·175	2 F.	Smooth.
26	32	2·63	0·024	0·282	2 F.	Smooth.

Table XVII.—*Embreville Iron.*

Comparison analysis test-pieces with pigs at random from the cast.

Series No.	Cast No.	Test-pieces.			At random.		
		Silicon.	Sulphur.	Phosphorus.	Silicon.	Sulphur.	Phosphorus.
1	364	1·36	0·012	0·347	1·35	0·015	0·350
2	782	1·29	0·021	0·239	1·25	0·029	0·231
3	525	1·61	0·031	0·260	1·63	0·035	0·268
4	383	1·86	0·012	0·189	1·91	0·018	0·180
5	220	1·95	0·023	0·182	1·95	0·020	0·186
6	203	1·37	0·021	0·237	1·30	0·028	0·229
7	781	1·57	0·031	0·260	1·62	0·035	0·265
8	238	1·79	0·028	0·199	1·67	0·019	0·189
9	679	2·00	0·011	0·175	2·02	0·009	0·170
10	1	5·19	0·032	0·248	5·07	0·039	0·238
11	523	2·28	0·071	0·167	2·28	0·083	0·160
12	755	2·25	0·024	0·182	2·19	0·020	0·178
13	840	2·10	0·016	0·144	2·11	0·016	0·157
14	50	2·86	0·133	0·334	2·78	0·138	0·340
15	54	2·39	0·108	0·249	2·33	0·110	0·253
16	312	0·66	0·078	0·176	0·66	0·084	0·181
17	278	0·55	0·109	0·211	0·53	0·120	0·209
18	313	0·62	0·140	0·160	0·65	0·150	0·166
19	193	1·05	0·023	0·229	1·08	0·016	0·233
20	236	1·21	0·063	0·183	1·20	0·051	0·180
21	366	1·22	0·016	0·243	1·26	0·019	0·239
22	745	0·83	0·023	0·217	0·81	0·025	0·209

Test-pieces, two to four in number, taken at time of cast, drillings mixed in equal *amounts. Pigs* at random drilled in nine places, drillings mixed.

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Therefore it was of great importance to them to use the coke freest from sulphur; but they came to the conclusion that with care they could melt the iron in the cupola. Very many years ago Sir William Fairbairn attempted to ascertain what effect re-melting of iron in the cupola would have upon it, and he found that by each re-melting it deteriorated in quality when tested by the tensile test. Sir William did not trace what this was due to, but he (Mr. Snelus) found that, following Sir William's experiments, and comparing them with his own, this deterioration was due to the iron taking up the impurities from the coke at each successive melting. It took up sulphur and phosphorus. Of course, if they could keep the slag thoroughly basic, they would, in all probability, to some extent absorb all these elements. But in the cupola it was not possible to use a too basic slag. He thought this was the most important point in connection with the foundry practice.

He was very glad that the author of this paper was not going to quite exclude the chemist from all the operations of steel-making. They would remember that, in the discussion on Mr. Sandberg's paper, it was suggested that the chemist's occupation was gone, and that the tup test was quite enough for the rail. But the author of this paper, by suggesting that users of iron should not depend entirely upon eye examination of the fracture, but that they should call in the chemist, and use both aids to ascertain the quality of iron, showed that he did not mean to dispense with the chemist altogether. He thanked the author on behalf of the chemists for leaving them an "open door."

Mr. AINSWORTH (Consett) said there was one point to which he wished to refer. Attention had been called to the influence of sulphur, and that it might be taken up from the coke in the cupola. There was another source which had not been mentioned, and that was the moulding composition. He had found, more particularly in ingot moulds, that a large amount of sulphur could be taken from the composition. They did not suspect it at first, but ultimately traced it to this source. It was found largely on the outside of the casting, decreasing gradually towards the middle of the metal, and again regularly increasing to the

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this, but if the author would give his proofs they should have one of the most interesting micrographic papers that had been presented to the Institute.

Mr. HARBORD quite agreed with Professor Arnold with reference to the paragraph he had called attention to on the influence of phosphorus upon the carbon. For many years he was connected with a works making cinder iron, and he never noticed any difference in the fracture between pig irons containing 3½ per cent. phosphorus (when the carbon and the silicon were the same) and the iron containing 0·6 per cent. of phosphorus; and in fact it was no uncommon thing to find masses of kish or graphite associated with the phosphoric iron. There was one thing he regretted the author had not gone more completely into, and that was the condition of the carbon. Quite lately he had been examining samples of cast iron identical as far as general analysis went, except that the silicon was slightly lower in one case than the other. The total carbon, the graphitic and combined carbon were the same in each case, but there appeared to be a difference in the state of the combined carbon—when both samples were compared by the colour test one gave double the percentage of the other. The sample with higher colour carbon gave tensile strain of three to four tons per square inch higher than the other sample, and the iron was much softer to machine. He did not know how far the special properties of cold-blast iron were affected by condition of carbon, but it seemed to him that it was an important point, and he thought a very good deal of work might be done with advantage in the investigation of state or condition of carbon in different cast irons.

Mr. W. H. BLECKLY, Vice-President, thought that members accustomed to foundry practice in England would agree with him that their general custom was to use square test bars, and he had never seen any cast-iron bars used for testing purposes except in that form. The author made a valuable suggestion that preference in all cases should be given to round bars. He thought it would be quite worth their while to try the testing of round bars, which would be a new experience to most of

[illegible] The proportion of [illegible] per cent. in the [illegible] did not seem [illegible] for a [illegible] material; [illegible] might likely enough be due to a [illegible]. [illegible] the practice of purchasing foundry iron by [illegible] by fracture alone, he thought the American [illegible] might well be followed in other countries. He had also [illegible] in Russia last summer that it was customary to [illegible] sample of each cast both in sand and chill, and the frac- [illegible] with a piece of the accompanying slag, were preserved in a [illegible] in the cast-house, so that the working condi- [illegible] of the furnace could be readily ascertained at any time.

Mr. A. [illegible], Member of Council, had only one observation [illegible] about this very valuable paper. He should have liked [illegible] the author say something about another element [illegible] very often had to be taken into consideration in foundries, [illegible] in Belgian works. They very often put tin as a [illegible] into the pig iron in quantities varying from 1 to 2 per [illegible]. They obtained castings which were very [illegible] the inside of the cylinders being only worn in a slight [illegible]. He did not know how tensile strength and elongation [illegible] with this kind of material; but he thought that the paper, [illegible] was very well written, ought to be completed by a refer- [illegible] such kind of mixtures.

Mr. W. [illegible], Hon. Treasurer, said it struck him as [illegible]

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the Institute. It was a paper that they must take home and go into carefully to see what the practical results of following the advice it contained would have upon their manufacture. One thing struck him especially, and that was the analysis of the pig iron, which was a very much better analysis than they were accustomed to find in the North of England and Cleveland, where his own works were, and no doubt they got better material and castings from this pig iron than Cleveland people could make from theirs without very material alteration in their mixtures and improvements in their quality. He observed phosphorus was only 0·0177; and the manganese he regarded as exceedingly useful as an admixture in forge work and for puddling purposes. He was speaking now of manufactured iron, and not of iron used for castings. The silicon also was low; and taking it altogether the elements were exceedingly favourable for making good material. He trusted that they would take all the advantage they could from the information and details, especially from the assurance they had received from Professor Howe, that the quality of the material was satisfactory, and that the writer might be relied on for every statement he had made in his excellent paper.

Mr. E. WINDSOR RICHARDS, Past-President, said that the paragraph in the paper relating to phosphorus had caused him, as well as Professor Bauerman and Professor Arnold, some amusement. The author had told them "that phosphorus unquestionably had a tendency, *per se*, to convert graphitic carbon into the combined state." He then gave them his best proof of that by citing a sample of basic pig iron, which, he says, "is almost always pure white and very brittle," caused by phosphorus. The author was entirely wrong in his conclusion, for phosphorus had nothing whatever to do with the white iron so produced. That white iron had been purposely produced in the blast-furnace, and had to be used in the manufacture of steel, and, of course, should contain as low a percentage of silicon as possible, and as little fuel had been used in the blast-furnace to produce that iron as possible, so that the silicon might be kept low. He pointed this out, as he hoped the author would alter his proof, because he was wrong in his conclusion.

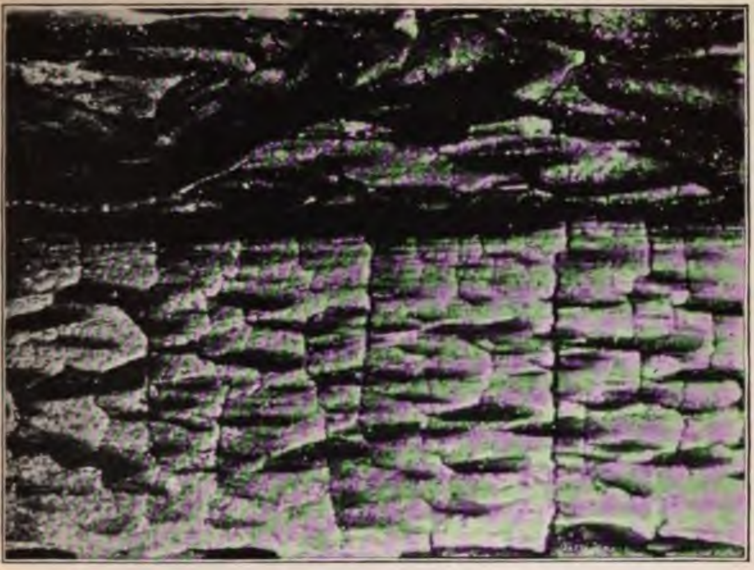
our worthy Treasurer that they might believe every word in the paper, he was afraid it was really necessary to mention it again. Evidently the author had not spent many anxious hours round the bottom of a furnace making phosphoric pig from a mixture containing gas coke and cinder as they did in the Black Country. There he might know that this iron had 2, 2½, and 3 per cent. of phosphorus, and all the time they were getting this high percentage of phosphorus they were still anxious in case the cloven hoof should show itself with a portion of grey in the centre. To produce a pig iron containing only 0·05 per cent. of sulphur, and to be compelled to use a very large quantity of gas coke which contained nearly 2 per cent. of sulphur, sometimes was a very difficult matter without having a very basic slag. It was well understood that it was necessary with the basic slag to have a very high temperature. But manganese was put in to increase the fusibility of the slag, and in that way the iron might be produced with a comparatively low temperature. The blast-furnace managers in making this basic pig iron found great difficulty in keeping the silicon down to below 1 per cent., and the Black Country men would not have it unless it was below 1 per cent., and sometimes with the 2 per cent. of manganese and with those high percentages of phosphorus the matter of 1¼ per cent. of silicon would produce a grey core, showing that it was the presence of the manganese, and the absence of the silicon, that had determined the production of a white iron. With regard to the effect of metalloids in iron there was nothing very new in the paper. Most of that would be found in the investigations of Mr. Turner made some years ago. It was very clearly shown there that the silicon produced this graphitic carbon, and tended to make the combined carbon lower, and the manganese and sulphur did the whitening. It seemed to him that the phosphorus had very little to do in producing graphitic or combined carbon. It would be better to have a little more light thrown upon the effect of phosphorus upon the carbon present. Although of course the great point in connection with the properties of the pig iron would be the amount of metalloids and the *condition* of the carbon, still he thought it would be worthy of consideration to take up the question of the effect of the *quantity* of carbon present.

PLATE XXIII.

Fig. 1.

Fig. 2.

PLATE XXIV.



No. 3.

No. 4.

Plate XXV.

No. 5

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CORRESPONDENCE.

Mr. R. A. HADFIELD, Member of Council, sent the following contribution to the discussion :—

I have read with much interest the excellent paper by Mr. Guy R. Johnson, and think our Institute is greatly indebted to him for bringing this important research before us.

The influence of various metalloids upon the properties of the metal iron has already proved to be a subject of the greatest value and importance; but, so far as I am aware, Mr. Johnson's paper represents the first systematic research regarding the influence of varying percentages of different metalloids upon what we term "cast iron." In my own case I have already found the data given by Mr. Johnson of considerable technical value, and I wish him continued success in his experimental work.

As in the case of steel alloys, the whole subject is very complex; in fact, it is perhaps even more so than the latter, in which there is usually only one variable besides carbon, and the effect of this element is as a rule much greater than any other constituents, and consequently its presence often overshadows that of any other metalloid present. As regards cast iron, not only has the effect of other metalloids present to be considered conjointly with carbon not present in one form only, as is usual in steel, but in two or even three varying forms, combined, graphitic, and probably, as Mr. Summers of Chicago mentions in the paper referred to further on, in a graphitic temper form.

Mr. Johnson gives several interesting results in Table 4 of the effect of sulphur upon Embreville iron. They confirm in a remarkable degree the peculiar influence of sulphur upon cast iron, as noticed in connection with the well-known Swedish Finspong iron. Ten or twelve years ago I well remember seeing one of the Finspong chilled projectiles, that is a projectile with chilled head and soft body, tested at Shoeburyness. Although of cast iron, to the astonishment of every one, it did not break up against the plate as did all the other cast-iron shell tested, but set up, and seemed rather to possess the characteristics of a soft steel casting than those of the material we know as cast iron.

According to Mr. Johnson's tests the Embreville iron contain-

able to select moderately cheap iron in this country, which, on mixing, would give almost any result that they aimed at, and that it is not necessary to purchase expensive brands with a reputation, as they could use cheaper material, and, with the aid of an analyst at their works, be able to synthetically produce from the cheaper pig iron results as good, if not superior, to the results they were obtaining to-day with the more expensive brands. A chemist in an iron foundry, in his opinion, was an absolute necessity, especially where high-class engineering castings were required. The results given by Mr. Johnson would be a very good guide to work to. He again complimented Mr. Johnson, and hoped that his valuable paper would be of great service to English founders.

Mr. Guy R. Johnson, in reply to the discussion on his paper, sent the following communication, dated December 8, 1898:—

Before replying to the various questions put, I wish to thank the members for their kind reception and the lenient tone in which they have discussed my paper.

The principal difference of opinion seems to be upon the statement that phosphorus, *per se*, has a tendency to convert carbon into the combined form. It is quite possible that I may be in error as to this point, but I should like to have Mr. Windsor Richards's grounds for stating so positively that this statement is incorrect. My attention was first called to this matter several years since, at one of the few furnaces in the States where basic pig iron was ever produced in large quantities. At the furnace, when a great deal of experimenting was done, the iron was practically pure white, or slightly speckled white. In this iron the manganese ran from 0·38 up to 2·07 per cent. Yet, oddly enough, the iron which was highest in manganese, although below 1 per cent. in silicon, was the greyest iron produced during the campaign, which would seem to indicate that manganese had little to do with the grade. The following analyses of Embreville iron also seem to indicate this:—

Cast.	Grade.	Si.	S.	P.	Mn.
1313	2	1·09	0·021	0·184	2·76
468	3	1·07	0·029	0·202	2·11
442	3	1·06	0·030	0·203	1·00
300	2	1·09	0·029	0·175	0·82
1807	2	0·83	0·019	0·176	0·84
1929	Mottled	0·83	0·019	1·210	0·55

[redacted]

[redacted]

of Mr. A. Vathaire's work, *Études sur les Hauts-Fourneaux.* The effect seems to be a double one. The specific gravity of lead being greater than that of iron, it should apparently remain unoxidised in the ladle, as it would were it not for the oxygen in the iron. This seizes upon the lead, forming lead oxide, which bubbles up through the molten iron, and in its passage facilitates the mechanical liberation of graphite, which floats up in great quantities. The resulting iron is close grained, and, as Mr. Greiner says, wears well. Possibly this explanation is erroneous, but we do not know much yet about the influence of oxygen on cast iron, except that probably it is a deleterious element.

I regret not to be able to oblige Professor Arnold with a micrographic proof as to the effect of 0·04 to 0·05 sulphur, nor in my opinion is it necessary, as all men engaged in the foundry business, using modern chemical methods, will assure him that the difference between 0·07 per cent. of sulphur and 0·12 per cent. of sulphur in ordinary castings makes all the difference between a close-grained casting, which can be easily machined, and one which it were probably better to return to the cupola. From a good deal of actual experience I can say that by using sulphur properly, it is possible to vary the character of the castings with identically the same analysis, except as to sulphur, from soft to hard, and that the effect of as little as 0·02 can be observed.

The following analyses, taken from hundreds of similar ones, will show the difference made by less than 0·5 sulphur :—

Cast.	Grade.	Si.	S.	P.	Mn.
953	1	0·99	0·016	0·161	0·56
957	2	0·98	0·021	0·185	0·60
2054	3	1·40	0·030	0·198	0·63
1074	G. F.	0·90	0·050	0·190	0·64
1183	M.	0·65	0·060	0·246	0·32

The fact is that our experience, which is given as a result of nearly four years' careful attention, is that, with the other elements about normal, below 0·030 per cent. of sulphur, Nos. 1 and 2 grades may be expected, above 0·03 and below 0·05, No. 3 to G. F., above 0·05 to 0·07, G. F. to M., above 0·075, hard mottled or white.

Finally, in answer to questions by Mr. Harbord and Mr.

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[redacted]

Visit of H.M. the King of Sweden.

At this stage all the members and ladies who accompanied them rose, as it was announced that the King was about to enter the hall. His Majesty entered, accompanied by their Royal Highnesses the Crown Prince, Prince Carl, and Prince Eugen, and was conducted to the raised daïs by the President.

Addressing the King, the PRESIDENT said it was his great privilege to thank his Majesty, on behalf of the members of the Iron and Steel Institute, for the very great honour conferred upon them. The high position that his Majesty filled in literature, art, and science was known throughout the world, and the interest his Majesty took in metallurgy was shown by the great honour he had conferred upon the Institute by allowing himself to be nominated an honorary and honoured member of the Iron and Steel Institute. The gracious recognition of his Majesty, and the courteous reception accorded by all his Majesty's subjects to the Iron and Steel Institute, would make this visit the most memorable in the history of the Institute.

The KING OF SWEDEN, in reply, said: I beg to return my most heartfelt and sincere thanks for the greeting which I have received from you on coming to take part in your meeting to-day, and still more so for the rare and highly valued distinction conferred upon me by the Iron and Steel Institute in calling upon me to be one of its honorary members. I welcome you all to my country, and I beg also to express my sincere good wishes for your work.

His Majesty then took a chair beside the President, and listened attentively to the reading of Professor Roberts-Austen's paper.

Professor ROBERTS-AUSTEN gave a summary of the following paper:—

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Noble has shown,* in such a gun as ordinarily employed there would be no less than 60 foot-tons of energy absorbed in producing rotation of the projection.

The author is also greatly indebted to Lieutenant-Colonel C. F. Hadden, R.A., Chief Inspector of the Ordnance Department at the Royal Arsenal, Woolwich, for a portion of a 3-inch steel armour-plate, which a "glancing" shot had struck, producing an indentation 0·5 inch deep, 5·1 inches long, partly by compressing the metal and causing it to flow, and partly by tearing portions of metal from the surface of the plate. This indent was produced by an ordinary 6-pounder hardened armour-piercing projectile, and the velocity at the point of impact was 1740 feet per second, and the striking energy would therefore be 126·7 foot-tons.

As regards the action which might be anticipated to occur during the erosion of an "A" tube, the following facts must be remembered. The temperature produced by the explosion of cordite, which was the propellant employed in the case of the tube in question, would be very high. The heat transmitted to the surface of the tube would, however, soon be abstracted by the mass of metal in the gun. This rapid heating of the interior of the tube, followed by more or less rapid chilling by this transmission of the heat, might therefore be expected to occur. Hence there are possibilities of more or less elaborate changes due to the thermal disturbance caused by merely firing the gun. The mechanical effect of the projectile passing along the tube has also to be considered, and the results should prove to be of interest, as the effect of work in producing molecular change in steel has long been a subject of study by Osmond, Barus, Carus Wilson, and others. The explosion produced by cordite would produce in this gun so high a pressure as 15 tons on the square inch. The problem, therefore, becomes a complicated one, which micrographic examination should render it possible to readily elucidate. First as regards the composition of the steel. The tube was a perfectly normal gun-steel, containing about 0·3 per cent. of carbon and 0·6 per cent. of manganese. The respective amounts of sulphur and of phosphorus did not exceed 0·05 per cent., and the amount of silicon was not more than 0·15 per cent. As regards treatment, the

* *Royal Society Proceedings*, vol. l. 1892, p. 409.

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carbon in the layer. So far as is at present known, the formation of martensite would demand this complete diffusion of the carbon. It is even possible that the layer may be a deposited one, composed of the detritus of the eroded matter. Against this view there is the fact that in some cases the ferrite bands fade away as the altered layer is approached. In other cases fine lines of ferrite pass into the altered layer. My friend M. Osmond (of whose counsel I have gladly availed myself) considers that, in a matter of so much importance, it would be unwise to express a definite opinion at present.

I have elsewhere * shown that when a projectile strikes an armour-plate it may, under certain conditions, produce in the solid steel a "splash" which resembles that produced by a sphere falling into water. I have also † shown that the penetration of carbon into iron obeys the ordinary law of diffusion of salts into water.

It is noteworthy that the surface of the "lands" over which the projectile has passed are traversed by cracks at right angles to the length of the "lands."

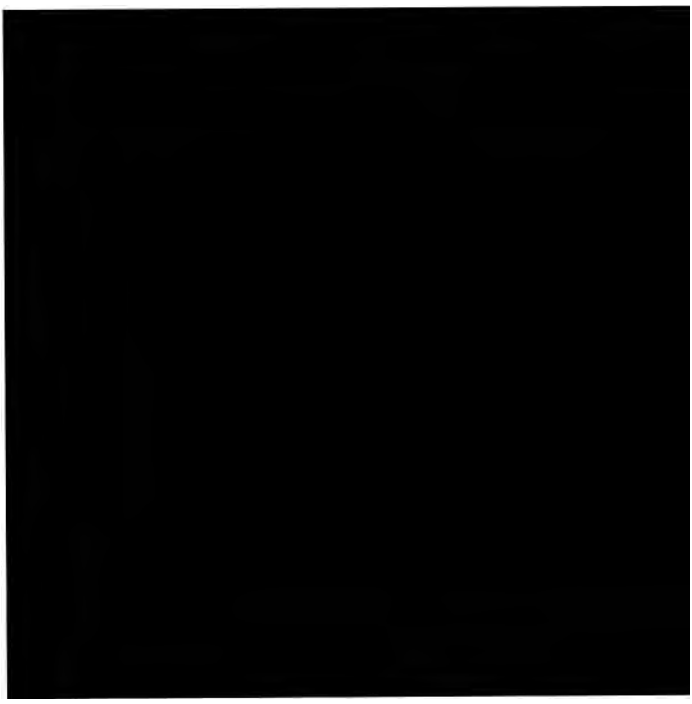
With reference to the armour-plate struck by a glancing shot, to which reference has been made, I do not find that the microstructure of the armour-plate has been altered by the impact.

The paper is illustrated by a series of micro-photographs, carefully prepared by Mr. W. H. Merrett, and by wall diagrams. (Plates XXIII. to XXV.)

Fig. 1 shows the section of the "A" tube eroded by gas. Fig. 2 is a section of a "land" and "groove," the dotted line *a b* showing the original rifling of the bore of the gun. It will be evident, therefore, how much material has been removed by erosion, as shown by *c*, *d*, *e*. The magnification is in this case about 3·3 diameters. Fig. 3 is a plan of a "land" and "groove," showing the eroded surfaces. The lighter portion is the raised "land," and it will be observed that there are transverse fissures.

Fig. 4 shows a section, magnified 117 diameters, of the driving edge of the groove. It will be seen that the altered layer resembles a geological deposit, and probably consists of eroded matter transferred from another part of the bore and welded in

* British Association, Discourse. Toronto, 1897. *The Times*, August 23, 1897.
† *Journal of the Iron and Steel Institute*, 1896, No. I. p. 139.

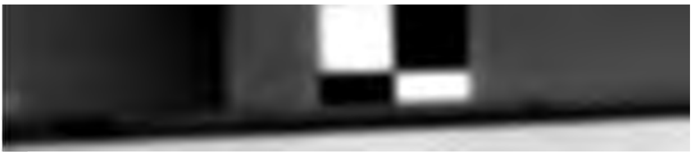


DISCUSSION.

The discussion was opened by Mr. WINDSOR RICHARDS, Past-President, who said he was in hopes that the President-elect (Professor Roberts-Austen) would have been able to inform them as to how erosion was to be avoided. He had the pleasure of meeting a very large manufacturer of guns only a few weeks ago, and he informed him (Mr. Richards) that this question of erosion was absolutely settled, that there was no erosion whatever, and that he (Mr. Richards) would endeavour to obtain a description of the arrangements carried out; and if he was successful he would hand them to the Secretary of the Institute.

Mr. G. J. SNELUS, Vice-President, ventured to suggest to Professor Roberts-Austen that they who had not been able to study the question so thoroughly would gain more information if he would add to his paper the composition of the gases produced by the cordite, or whatever was used, and if possible the temperature which was produced by their explosion. Both these elements must be taken into account; but he entirely agreed with him, that the chief cause of erosion was entirely mechanical. The photographs placed before them were most interesting, and required deep study. He had had an opportunity of examining them for a short time, but everybody should examine them with the greatest possible care. He ventured to say that they were the finest micro-photographs that the Institute had yet seen, and he thought that Professor Roberts-Austen should have their best thanks for the attention he had given to the subject.

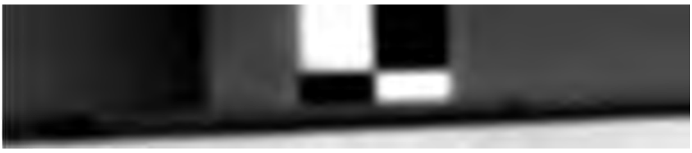
Professor J. O. ARNOLD said he should like to ask Professor Roberts-Austen whether he had ever clearly obtained the transition stages of the carbide, troostite, and other things mentioned. He had examined gun-tubes almost identical in composition with those dealt with by Professor Roberts-Austen, and in every respect but that the structures agreed with his. It would be well for students to know if these two forms had been observed in guns, and if so, their characteristic features. That was a point in which



very small bored perforations for the escape of the gases. The erosion produced in these passages fairly reproduced the furrowed surfaces seen in meteoric bodies, and which in the latter case are attributable to the resistance of the air to the passage of bodies moving with planetary velocities at their entrance into the atmosphere.

Professor HOWE said Professor Roberts-Austen had called attention to a very remarkable phenomenon, that the metal in the interior of the gun tube, although it had been very highly heated and very suddenly cooled, was not in the condition of martensite. It appeared to be only a very thin shell in the interior of the tube, which became highly heated, and it was evident that the cooling of this shell by the very great mass of the gun surrounding it must be very rapid. How came it that this metal, though highly heated and suddenly cooled, did not contain martensite? Two explanations suggested themselves. Either that martensite formed at the moment of explosion, when the temperature of the interior of the tube became high, but that this martensite found time during the subsequent cooling of the interior of the tube to change back to pearlite and ferrite; or else that the heating of the interior of the tube was so extremely rapid, and that the cooling followed on this heating so rapidly, that there was not time for martensite to form. In other words, the absence of martensite was accounted for either by supposing that the cooling was sufficiently slow to permit the martensite which had formed to decompose, or else that both heating and cooling were so rapid that martensite had no time to form. This second supposition implied that the formation of martensite was not instantaneous, but occupied an appreciable length of time, a very interesting and important application.

Now of these two explanations, the former seemed hardly reasonable, because the retention of martensite did not seem to require an extremely rapid cooling. Thus, when a bar of considerable dimensions was suddenly cooled by plunging it in water, there might be martensite in its interior, yet the rate of cooling in the interior should be very much slower than the cooling of the interior of the gun tube. They were thus thrown back on the second explanation.



brief. Mr. Snelus had asked him to determine the temperature of the gases. That was a matter of extreme difficulty, as hitherto the only method they had of determining such high temperatures was afforded by the use of platinum thermo-junctions, and the temperature of the explosion was often greater than the melting point of platinum, so that the most readily available method of determining the temperature of the explosion failed. Therefore there was great difficulty in ascertaining the temperature of an explosion. With regard to the points raised by Professor Arnold, he was perfectly satisfied that the transition forms of carbide, troostite, and sorbite really existed; but he had better try to convince Professor Arnold of their existence by the aid of diagrams and by photographs than by prolonging the discussion. The erosion produced did not involve the presence of solid particles, but might be perfectly well effected by gas. With regard to the streaks and fissures which appeared on the surface of the "lands," similar transverse fissures occurred also in certain rails, and were often a notable cause of fracture.

A vote of thanks was heartily passed to Professor Roberts-Austen for his valuable paper. His Majesty the King then took leave of the meeting, shaking hands with the President and Members of the Council.

The PRESIDENT announced that, owing to want of time, the important papers by Baron Jüptner and Professor E. D. Campbell would be taken as read, and proposed a hearty vote of thanks to the authors.

It should be noted that in this figure the freezing-point of pure (electrolytic) iron is taken at 1600° C., whilst in the former paper it has been taken at 1500° C. (or 1530° C.).

Unfortunately there exists no data as to the latent heat of fusion of pure iron. It is true that Person has given a general formula for the latent heat of fusion of solid bodies—

$$w=0{\cdot}00167\,K\left(1+\frac{2}{\sqrt{d}}\right),$$

where K is the modulus of elasticity and d the specific gravity; but although this value is fairly satisfactory in the case of lead, tin, bismuth, zinc, and silver, it is by no means safe, and the value it gives for iron, viz.—

$$w=57 \text{ calories}$$

($K=20{,}000$, $d=7{\cdot}8$), is so high, and differs so considerably from Gruner's figures (which, of course, are likewise by no means unimpeachable), that it appears advisable for the present to retain the formerly taken value of 20 calories.*

From these data we arrive at the following conclusions:—

I.—*Freezing-Points of Fluid Iron-Carbon Alloys.*

As with all solutions, the fluid iron-carbon alloys possess only at one determined composition a single freezing-point. This eutectic iron-carbon alloy consists of iron, 95·7 per cent., carbon, 4·3 per cent; and its freezing-point is situated at 1130° C.

Every other iron-carbon alloy possesses two clearly distinct freezing-points, of which the higher, in the case of alloys poor in carbon, corresponds to the separation of solid iron, but in the case of rich carbon alloys to the separation of graphite, whilst the lower one represents the freezing-point of the eutectic alloy.

Let us next consider the temperature of separation of solid iron; we have melting-point of pure iron in absolute temperature—

$$T_0=1600^\circ+273^\circ=1873^\circ,$$

and hence the molecular melting-point depression—

$$E=0{\cdot}0198\times\frac{1873^2}{20}=3273,$$

* The latent heat of fusion of the metal nickel, so similar to iron, amounts, according to Dr. J. Richards (*Journal of the Franklin Inst.*, 1892, February), only to 4·64 calories.

that is to say, the molecule of the dissolved carbon in molten iron is monatomic.

This value also does not at the first glance appear to be an impossible one, though a little reflection immediately leads to a different opinion.

For the lowering of the fusion-point we have, as is known, the equation

$$t=\frac{E}{M}m,$$

an equation in which t and m are variable, but E and M are constants, and which represents a straight line.

As long as this line goes through the freezing-point of one of the constituents of the solution, the following expression

$$\frac{t}{m}=\frac{E}{M}=\tan a$$

represents the tangents of the angle of inclination of these straight lines to the m axis.

Under these circumstances, tangent a, and therefore also M, must be constant; that is to say, so long as the fusion-point depression curve, starting from the fusion-point of the one constituent of the solution, forms a straight line, the molecular atomicity of the second constituent of the solution remains unaltered. This is the case in the curve AB for $C=0$ to $C=1{\cdot}9$ per cent., we get the molecular weight of the dissolved carbon for this straight portion of the curve in the following way. If, for example, we put $C=1{\cdot}5$ per cent.—

$$t=1600-1400=200^\circ \text{ C.}$$
$$E=1218{\cdot}6 \text{ (as above), and}$$
$$M=\frac{1218{\cdot}6\times 1{\cdot}5}{200}=9{\cdot}14,$$

that is to say, the dissolved carbon molecule can only consist of $\frac{3}{4}$ atoms, which is impossible. The impossibility of Person's value for w is thus shown, and it appears therefore justifiable for the present to retain the formerly taken value.

Taking in our further consideration the values

$$w=20 \text{ calories and}$$
$$E=3273$$

we obtain—

If we calculate in the same way from the curve *BD* the molecular atomicity of the dissolved carbon—even if the calculation cannot be regarded as reliable—we get—

C. per Cent.	Fusion-Point ° C.	Fusion-Point Depression to ° C.	*m.*	*M*	*n.*
4·3	1130	474	4·49	31·27	2·61
4·5	1150	454	4·82	34·73	2·89
5·0	1208	392	5·26	43·90	3·66
5·5	1260	340	5·82	56·01	4·66

If now we turn our attention to the fusion curve of the fluid eutectic alloy *aBc*, we find in it the following points:—

C. per Cent.	Fusion-Point ° C.	Fusion-Point Depression to ° C.	*m.*	*M.*	*n.*
2·0	1113	487	4·493	30·19	2·51
2·5	1115	485	...	30·32	2·53
3·0	1117	483	...	30·44	2·54
3·5	1120	480	...	30·64	2·55
4·0	1127	477	...	30·83	2·57
4·3	1130	474	...	31·27	2·61
4·5	1130	474	...	31·27	2·61
5·0	1130	474	...	31·27	2·61
5·5	1130	474	...	31·27	2·61

These alloys contain about equal amounts of the 2 and 3 carbon molecules.

Taking the specific gravity of the metal at its fusion-point as 7·4, we get as the approximate value for the osmotic pressure of the dissolved carbon the following figures:—

° C.	C. per Cent.	*n.*	Weight of Carbon in 1 Litre of Metal.	Weight of 1 Litre of Carbon Gas in Grammes.	Osmotic Pressure, Atmospheres.	
					Total.	Per 1 per Cent. C.
1500	0·7	2·0	50·8	0·164782	308·2	440·3
1400	1·47	2·0	108·78	0·174641	623·0	423·8
1300	2·2	2·03	162·80	0·188533	860·8	391·3
1200	3·3	2·25	244·20	0·228157	1070·1	324·3
1130	4·3	2·60	318·20	0·270746	1175·4	273·4
1200	4·9	3·60	362·60	0·357052	1015·7	207·3
1260	5·5	4·66	407·00	0·532697	768·0	138·9

or for 1 kilo of pig iron with 3 per cent. graphite—

$$q = \frac{10 \times 3 \times 1419}{1000} = 42{\cdot}57 \text{ calories.}$$

II.—*Influence of Silicon and Manganese on the Freezing-Point of Fluid Iron-Carbon Alloys.*

If we now bring our newly-acquired knowledge to the consideration of those iron tests which formed the basis of our former paper, we find as follows:—

The average molecular atomicity of the carbon in Swedish white pig iron, as it was then calculated in Table V. ($n = 2{\cdot}53$ with $4{\cdot}10$ per cent. C), agrees excellently with the newly-found value ($n = 2{\cdot}44$ for 4 per cent. C, and $n = 2{\cdot}62$ for $4{\cdot}5$ per cent. C).

If the new value for the molecular atomicity of the dissolved carbon for $3{\cdot}29$ per cent. C (roughly $n = 2{\cdot}27$) be made use of in the equations relating to the hæmatite pig, we get for $M = 55{\cdot}82$—

$$n_{Si} = \frac{55{\cdot}82 \times 0{\cdot}0874}{3{\cdot}29 + 2{\cdot}45 - 55{\cdot}82 \times \frac{0{\cdot}2742}{2{\cdot}27}} = \frac{4{\cdot}8787}{5{\cdot}74 - 6{\cdot}78} = -\frac{4{\cdot}8787}{1{\cdot}00},$$

thus a negative result. This may either arise from the fact that the atomicity of the dissolved carbon molecule does not depend only on the content of carbon, but may also be influenced by the content of the other accompanying bodies; partly, however, from the fact that $M = 55{\cdot}82$ was reckoned on the supposition that—

$$\theta_0 = 1500 + 273 = 1773 \text{ (for iron) and } E = 3112.$$

We must therefore re-reckon all our formerly obtained values from our new data, and then we obtain—

No.	Composition.		Fusion-Point T_0.	Molecular Fusion-Point Depression $E = 0{\cdot}0198 \frac{T_0^2}{w}$.
	Fe per Cent.	Mn per Cent.		
...	100·00	...	1873	3273
...	...	100·00	2173	4675
1	13·98	86·02	2131	4219
2	48·18	51·82	2028	4015
3	82·20	17·80	1926	3813
4	99·89	0·11	1873	3708
5	70·93	29·07	1960	3881
6	96·99	3·01	1882	3726
7	99·87	0·13	1873	3708

From the above figures it follows that we must modify our original conclusions in the following manner:—

1. The carbon and silicon molecule dissolved in the molten iron, or molten iron and manganese, consists of an equal number of atoms.

2. The atomicity of this carbon and silicon molecule is independent of the quantity of manganese present.

3. It increases, however, with the total content (expressed in carbon equivalents) of carbon and silicon.

4. In very dilute carbon (and probably also silicon) solutions (up to 2·5 per cent.) these molecules consist of two atoms.

5. The mean atomicity of the molecule increases from the above limits for 1 per cent. carbon or $\frac{3}{7}$ per cent. silicon by about 0·25 atom (but with higher percentages of both elements together about double this); and

6. It reaches in the case of a total of about 8 per cent. of C and Si (in C equivalents) to five atoms.

As is known, the osmotic pressure of equal quantities of carbon and silicon varies inversely as their molecular weight, so that we can readily calculate the *osmotic pressure of silicon* from that of carbon and obtain:—

Temperature in ° C.	Osmotic Pressure of 1 per Cent.	
	Carbon in Atmospheres.	Silicon in Atmospheres.
1500	440·3	188·7
1400	423·8	181·6
1300	391·3	167·7
1200	324·3	139·0
1130	273·4	117·2

Values considerably higher than in the former treatise.

From this is calculated for saturated solutions the maximum osmotic pressure at the fusion-point.

(*a*) For iron with 4·63 per cent. C (fusion-point = 1065° C.):—

$$P_{max} = 4{\cdot}63 \times 299 = 1384{\cdot}37 \text{ atmospheres.}$$

From this it further follows :—

Separation-Temperature.	C per Cent.	Fe_3C per Cent.	Fe Solution per Cent.	m.	M $(x=1600)$.
Ar_3	0·0	0·0	100·0	...	......
...	0·1	1·5	98·5	1·52	$M=\frac{1{\cdot}52\,E}{x-850}=0{\cdot}002023\,E.$
...	0·2	3·0	97·0	3·09	$M=\frac{3{\cdot}09\,E}{x-810}=0{\cdot}003911\,E.$
Ar_2	0·0	0·0	100·0	...	Since the quantity of ferrite separated at Ar_3 is not sufficiently well known, m and M cannot be calculated near enough, but approximately $M=0{\cdot}005\,E$.
...	0·1	1·5	98·5	?	
...	0·2	3·0	97·0	?	
Ar_{3-2}	0·3	4·5	95·5	4·67	$M=\frac{4{\cdot}64\,E}{x-720}=0{\cdot}005273\,E.$
...	0·6	9·0	91·0	9·89	$M=\frac{9{\cdot}89\,E}{x-690}=0{\cdot}010868\,E.$
...	0·86	12·9	87·1	14·81	$M=\frac{14{\cdot}81\,E}{x-670}=0{\cdot}015924\,E.$

For the solid eutectic alloy (perlite) approximately :—

$$M=0{\cdot}015\,E.$$

Now, E. D. Campbell has shown the great probability of the existence of iron carbides of the formulæ Fe_6C_2, Fe_9C_3, $Fe_{12}C_4$, and $Fe_{15}C_5$; and it is natural to attempt to identify Campbell's data with the values obtained above. In that case one would get fairly accurately the following results :—

Separation-Temperature.		Molecular Atomicity of the Iron Carbide.	Probable Formula of the Carbide.
Ar_3	850° C.	0·002023 E	$\frac{2}{3}$ (Fe_3C)
	810° C.	0·003911 E	1·5 (Fe_3C)
Ar_{3-2}	720° C.	0·005273 E	1·67 (Fe_3C)
	690° C.	0·010868 E	2·5 (Fe_3C)
Ar_{3-2-1}	670° C.	0·015924 E	5 (Fe_3C)

Even if these figures are by no means reliable, yet they do not contradict the fact shown by H. Saniter, that iron carbide begins to dissociate at 800° C. ; that is to say, that at a temperature

ON THE DIFFUSION OF SULPHIDES THROUGH STEEL.

[SUPPLEMENTARY PAPER.]

By E. D. CAMPBELL (University of Michigan, Ann Arbor).

On reading the account of Mr. J. E. Stead's unsuccessful experiments * on diffusing sulphides through steel, and his criticism of my work on the same subject,† I felt called upon to take up the work again, in order to try and determine whether any more information could be obtained regarding the conditions under which sulphides may be made to diffuse through steel.

My old stock of diffusing oxysulphide having been exhausted, I have made a new sample, which has given extremely good results. This sample was prepared by intimately mixing the following materials: 250 grammes of laboratory sulphide, containing 26·31 per cent. sulphur, 13·25 grammes of precipitated black oxide of iron, Fe_3O_4, and 42·65 grammes of manganese oxide, MnO_2. The object of adding the manganese dioxide was to see whether, if part of the iron was replaced by manganese, the oxysulphide produced would diffuse any more readily than when iron alone was present. The above mixture was placed in a close-grained clay crucible, melted, and poured, as soon as liquid, into an iron mould, precisely as in our former work in making our diffusing oxysulphides.

The sulphide thus produced showed the following composition:—

Oxides other than iron or manganese	4·56
Iron	59·30
Manganese	7·26
Sulphur	20·65
Oxygen (by diff.)	8·23
	100·00

* *Journal of the Iron and Steel Institute*, 1897, No. II. p. 95.
† *Ibid.*, pp. 80–94.

ment required about three hours. The heating was performed with access of air, so that, after cooling, the bar was found to be covered with a heavy scale, and the asbestos, on which the bar rested, was found to be soaked completely through, and to the extreme edges.

The scale was removed and divided into two portions—that from the upper and that from the lower half of the bar. These scales, as well as the asbestos which had absorbed the diffusing sulphide, were weighed, ground, and analysed to determine the amount of copper in each. The bar, after removing the scale, was weighed, then sawed vertically, so as to bisect the hole and show the extent to which diffusion had taken place. An examination of the hole showed that the sulphides had diffused almost perfectly, a few thread-like particles only having been found on one side of the hole; the metal on all sides of the hole showed no signs of being affected in any way, the outline being perfectly sharp, and the line between the plug and the sides of the hole being almost indiscernible. The bar was drilled, and the drillings analysed for copper, the amount remaining in the bar being thus determined. The distribution of the copper after the experiment may be best judged by the following table:—

	Weight. Grammes.	Per Cent. of Copper.	Weight of Contained Cu.	Per Cent. of Total Cu added.
Bar	402·00	0·026	0·1245	5·25
Asbestos . . .	35·42	5·80	2·0544	86·78
Upper scale . .	30·54	0·191	0·0570	2·41
Lower scale . .	22·09	0·153	0·0337	1·43
		Total . .	2·2698	95·87

Thus, as will be seen, 95·87 per cent. of the total copper added is accounted for, 90·62 per cent. having diffused through the bar. The original bar showed no traces of copper.

Experiment, June 6.—This experiment was made to determine whether the sulphides would diffuse in a non-oxidising atmosphere. A bar prepared similarly to the one used in the previous experiment was placed upon asbestos in the furnace. There was placed in the furnace also a couple of large pieces of charcoal,

some of the diffusiate is left in the middle. The lack of increase of sulphur is easily accounted for by the fact that the diffusion is performed in an oxidising atmosphere, and at the temperature at which the experiment is performed, steel being apparently decidedly porous, any small amount of sulphide in the steel would be oxidised, the sulphur passing out as sulphur dioxide.

I have sent a set of specimens to Mr. R. A. Hadfield, showing a bar, some asbestos, and oxysulphide used before heating; one showing bar, asbestos, and false bottom after heating; one showing bar and asbestos sawed through without removing the scale; and the specimens from the experiments May 30 and June 6.

The experimental work of the above-described has all been done by my assistant, Mr. Carl Sundström, and to the care with which he has performed the work the satisfactory results are due.

CORRESPONDENCE.

Mr. J. E. Stead, Member of Council, said he was exceedingly glad that his mild criticisms on Mr. Campbell's paper had resulted in more experimental trials being made. It was quite evident Mr. Campbell appreciated that it was difficult to conceive that diffusion would take place through solid steel without some of the diffusiate being left *en route* to the exterior, and he had now experimentally shown that some of the copper used in his more recent experiments had been retained in the mass of the steel itself. He (Mr. Stead) had not had time to further investigate the question in the direction followed by Mr. Campbell, but he had obtained, by different methods of investigation, several results, in which he had proved that sulphide of iron had diffused into steel, and was retained there to a very much greater extent than anything brought forward by Mr. Campbell. He hoped, when the opportunity arrived, to complete his experiments, and place the results before the Iron and Steel Institute.

VISITS AND EXCURSIONS AT THE STOCKHOLM MEETING.

In connection with the Stockholm Meeting an influential Local Reception Committee was formed at Stockholm, to make arrangements for receiving the Institute. The President of the Committee was Baron Gustaf Tamm, Governor-General of Stockholm, and President of the Jernkontor. Besides Baron Tamm, the Committee included the following forty-three noblemen and gentlemen: His Excellency Baron F. von Essen, M.P., Lord Steward; Mr. R. Åkerman, Ph.D., M.P., Hon. Member Iron and Steel Institute, Director-General of the Board of Trade; Mr. C. Aspelin, Fagersta; Baron C. J. Beck-Friis, Harg; Mr. T. Bergendal, M.I.S.I., Söderfors; Mr. G. F. Berndes, M.P., Stockholm; Mr. J. A. Brinell, M.I.S.I., Fagersta; Mr. P. J. Bråkenhjelm, Governor of the Province of Upsala; Count O. Cronstedt, Lord-in-Waiting; and Messrs. C. Danielsson, M.I.S.I., Uddeholm; G. Dyrssen, Captain R.N., Bofors; P. Erkisson, Hofors; H. P. V. Gahn, Wikmanshyttan; G. Geijer, Artillery Colonel, Stockholm; R. Geijer, Uddeholm; A. H. Göransson, M.I.S.I., Sandviken; F. Göransson, Sandviken; A. Herlenius, Artillery Captain, M.I.S.I., Storfors; G. Jansson, Uddeholm (Munkfors); J. C. Kjellberg, M.I.S.I., Stockholm; C. F. Liljewalch, Stockholm; C. C. Lindberg, M.I.S.I., Laxa; A. Lindman, Commander R.N., M.I.S.I., Iggesund; A. G. Ljungberg, M.I.S.I., Falun; E. J.

[illegible], Professor at the School of Mines, Stockholm; [illegible] Ph.D., M.P., [illegible] of the [illegible] [illegible] M.P., Governor of the Province of [illegible] Ph.D., Stockholm; [illegible] Governor of the Province of [illegible] Director and Professor of the School of [illegible]

The Executive Committee was a small one. [illegible] and [illegible] (Hon. Sec.). [illegible] of the arrangements made by this Committee, [illegible] manner in which the [illegible] members were received [illegible]

The proceedings began on August [illegible] with a [illegible] by the President and Council of the [illegible]

burg, and with an illustrated account of Dalecarlia by the Dalarne Railway Company.

In the afternoon, from 2.30 to 5 P.M., the members visited, by arrangement with the Svenska Teknologföreningen (Committee: Mr. A. Nordström, chairman, Mr. Ad. Ahlsell, Mr. M. Borgstedt, Mr. C. F. Ekerman, and Mr. J. Pihlgren), the following works and places of interest:—

(1) The new Gasworks of the city (Gasverket), half an hour's drive.

(2) The Dairy Machinery Works (Aktiebolaget Separator), Fleminggatan 14.

(3) Pottery Works (Rörstrand's Aktiebolag), Rörstrand.

(4) The Telephone Central Station, Malmskilnadsgatan 30.

(5) The Testing Laboratory of the Royal Technical High School, Drottninggatan 95.

(6) De Laval's Steam-Turbine Works (Aktiebolaget de Laval Ångturbin), at Jerla.

Banquet at Hasselbacken.

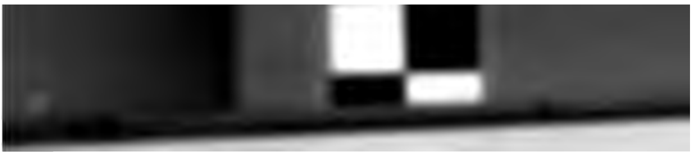
In the evening the members were entertained at dinner at Hasselbacken by the Association of Swedish Ironmasters. Baron Tamm presided, and there was a large attendance.

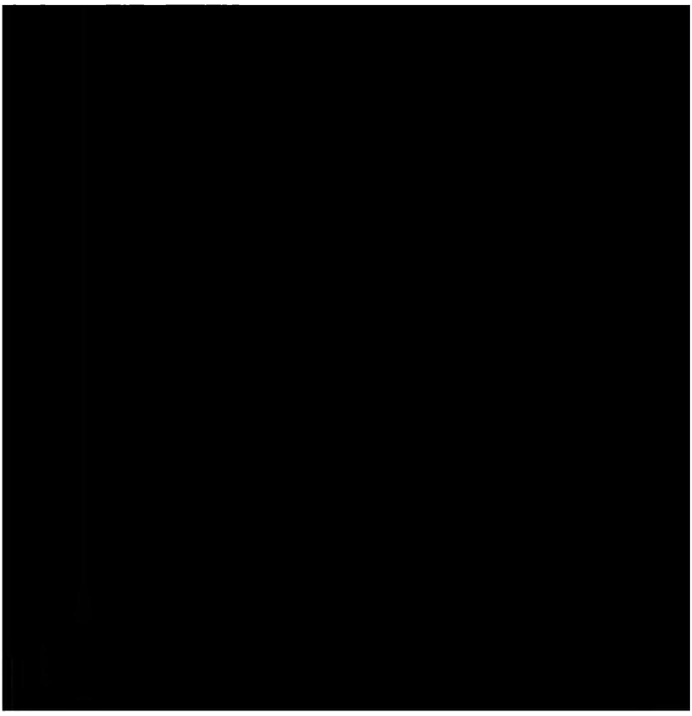
Baron Tamm proposed the first toast, "His Majesty King Oscar," and next gave the toast of "Her Majesty Queen Victoria." He said: It is about a year ago since the sixtieth anniversary of Queen Victoria's long and prosperous reign was celebrated by her true and loyal subjects, from all quarters of the globe, with enthusiastic demonstrations of their feelings of love and veneration. This homage resounded in all the countries of the world; also here in Sweden, where manifold intimate relations and the old affinity connect our people with yours, the very name of the beloved sovereign was an object of general sympathy, respect, and veneration. Another blessed and happy year has now been added to the sixtieth, and we cannot but rejoice with you and join in your noble feelings whenever that dear name is mentioned. The fact that her Majesty Queen Victoria is loved by everybody and everywhere within and without your country might easily be explained by a great many reasons. On this occasion it will be sufficient only to remind you of the glorious example she has set by her public life to all her contemporary sovereigns, not less than also to future monarchs of all countries, being at the same time an impersonation of all the best, noblest, and most sympathetic qualities of your British nation. I beg to propose

was by the spirit of energy and perseverance and love of freedom, respect for law that Englishmen, such as their honoured guests, went abroad, and wherever they went had taken with them the same spirit and planted it there. It was by this spirit that this special civilising influence had been brought out by England, and that was why he would give in the truest sense of the word the name of Great Britain. He proposed the toast of "Great Britain," with the wish that, as she had done so many times before, she would never forget that right was better and stronger than might. He then called upon his countrymen to give "hurrahs" for Great Britain.

Sir JAMES KITSON, Bart., M.P., Past-President, in responding, said that he found himself in a considerable difficulty. In the first place he had to respond on behalf of Great Britain to an eloquent speech made by one of the great politicians of Sweden. He also knew, what perhaps many of their Swedish friends did not know, that he had to speak in the presence of two distinguished English politicians, one who was a member of the late Government of the Queen (Mr. Edmund Robertson, Q.C., M.P.), and the other, who was the first and most distinguished advocate at the English bar (Sir Edward Clarke, Q.C., M.P.). Although the individual who addressed them was not of much moment, the country that he represented, and the section of the country which was honoured by being their guests that evening, was a great and an eminent one. It might interest them to know that Mr. Windsor Richards and himself that morning reckoned up the quantity of pig iron which was manufactured in the works controlled by the gentlemen who sat at the Council table of the Institute, and when he told them that they manufactured 2,500,000 tons of pig iron per annum, he hoped that they would be exalted in their estimation. They would know that this was about five times the quantity of iron which was manufactured by their great country of Sweden, and the country from which he came was happy in manufacturing about twenty times the iron which Sweden produced—happy for England that Sweden did not produce that quantity, happy for England that the Swedish people were able, notwithstanding all these enormities, to receive them in the gracious manner that they did. They were happy in their association with Sweden, because they had been indebted to Sweden for more than a century to their eminence as manufacturers of steel, because they had been able to draw from Sweden a magnificent quality of iron.

And now this Greater Britain found itself in face of another threaten-

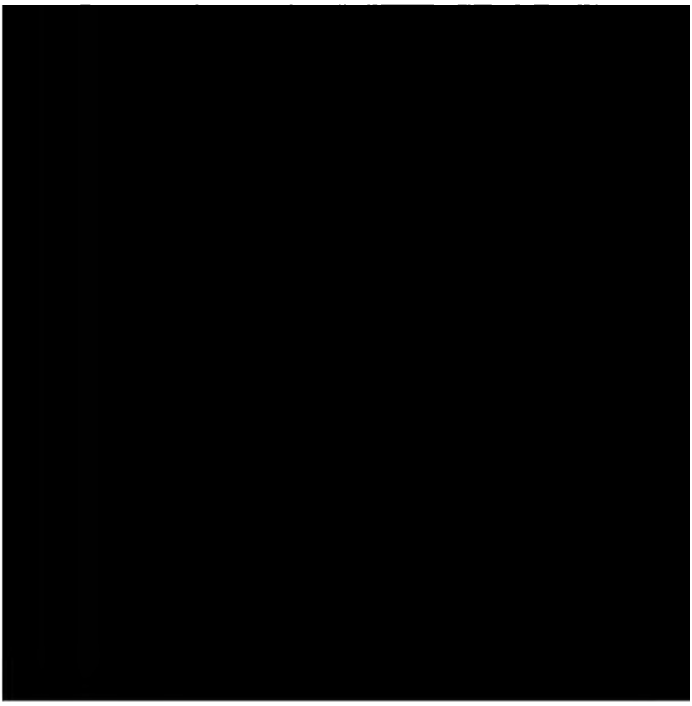




be mentioned was the absence of that jealousy which once characterised the steel works, especially in different countries, that was to say, the meetings of the Institute had caused the opening of a great many interesting works which used to be more or less closed up not only to real but also to imaginary rivals. Now that the old Jernkontoret had been happy enough to have the honour of receiving as guests its certainly much younger but nevertheless far bigger and more vigorous colleague, the Iron and Steel Institute, he felt proud of the honourable task of proposing a toast for the welfare of the Iron and Steel Institute.

Mr. E. P. MARTIN, the President of the Institute, in responding, said he had often felt that he was wanting in that eloquence so necessary in their President, and which he had never felt more than he did on that occasion. But he would endeavour to do what he could to reply on behalf of the Institute, and to thank Mr. Åkerman for his kind and complimentary references. Since their arrival in Sweden they had felt that they were not amongst strangers but amongst kinsfolk. The very great kindness that they had received on all hands, from the highest to the lowest, would ever be remembered by them all. The advantage their Institute derived from its cosmopolitan character had never been better shown than during that visit. They had enjoyed hospitality, he might say, in almost every quarter of the globe; at any rate, they had enjoyed hospitality in Belgium, France, Germany, Austro-Hungary, Spain, America, and Sweden, and one of those days they might go to China and Australia. His Majesty King Oscar had been graciously pleased to invite them to his palace, and he was about to confer upon the Institute the unprecedented honour of taking part in their proceedings, showing, as he always had done, the great interest he took in science and art.

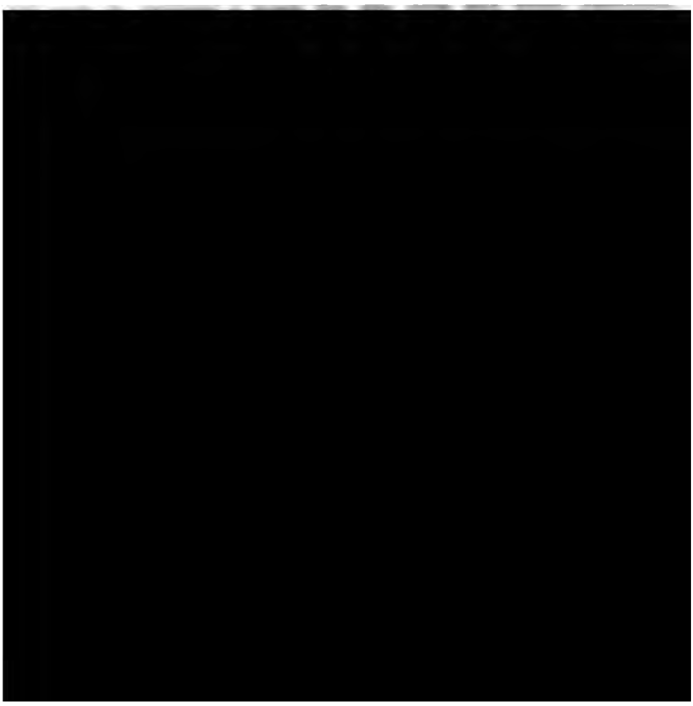
Professor W. C. ROBERTS-AUSTEN, C.B. (President-elect), said he believed that technically he was responding to the same toast as that to which the President had already replied, and he had nothing to add to what he had so sympathetically said except to assure them that not one of their guests, whatever their nationality, would ever forget their splendid reception in Stockholm. He had, however, been granted a special privilege that night, for he had been allowed to propose the health of their hosts that evening, the Jernkontor of Sweden, that great body of Swedish ironmasters who so adequately represented all these varied scientific and industrial interests which they as members of the Iron and



ficent building such as that in which they were received on the previous night, and the frieze around that building representing the metallurgy of iron from the raising of the ore to the Bessemer converter, and even longer as connected with the laboratory. Would that they had a building such as that at Westminster or Charing Cross. Naturally he was to couple with the toast the name of Baron Tamm. They already knew that he was Governor-General of Stockholm and President of the Jernkontor, and as President of the Reception Committee they all knew how intensely kind he and everybody associated with him had been. He hoped Baron Tamm would forgive them if they gave expression to their feelings not by the three hurrahs which were so endeared to them by home associations, but by another mode of expression, to tell him from their hearts that of which there was no doubt, that "He's a jolly good fellow."

Dr. Åkerman then proposed "The other Guests," who, he said, were largely representative of those who were connected with the government of the two nations. There was first the Master of the Royal Household, through whom they had been honoured with the gracious invitation to the royal banquet. To these gentlemen their best and most respectful thanks were due for the splendour which their presence had given to the dinner; and he hoped they felt themselves at home in this gathering of workers in the most useful and necessary of all the metals. Among the guests who also ought to be specially mentioned there were representatives of the Swedish Society of Engineers and Architects, whose works had been kindly opened to the members; and also the railway authorities, who would carry the party on excursions to some of their iron-producing districts. They further felt happy in seeing present the representatives of the Swedish Technical Society, and representatives not only of the Royal Ordnance Department, the School of Mines, and the Royal Mint, but also all the industrial works at Stockholm, which were open to visitors during the meeting.

Mr. Herbert, Secretary of the British Legation, and the Right Honourable J. E. von Krusenstjerna, the Minister of the Interior, returned thanks, and the proceedings terminated.



scholars? It is not to me to give any answer to it. But whatever we may have failed to do in this respect, one thing at least I might say—scholars grateful to our teachers have we been, are, and shall ever be.

"It is this feeling that I would express in the toast which I now propose for the British Iron and Steel Institute, and for its welfare."

The return journey, about 11 P.M., was marked by charming illuminations and fireworks, commencing at the palace and continued at all the villas and summer residences on the shores of the lake, the signal for the latter being given by the steamer carrying the Swedish visitors, so that there was a continued succession of surprises until Stockholm was reached, when a most charming entertainment came to an end.

Luncheon at Hasselbacken.

On Sunday, August 28th, the members and the ladies accompanying them were invited to a farewell luncheon at Hasselbacken. The chair on this occasion was taken by Dr. Åkerman, who had on his right Mrs. Martin and on his left Mrs. Roberts-Austen. At the lunch Mr. Martin, in the course of a short speech, announced that he had just received a telegram stating that the South Wales strike was settled.

After luncheon the company adjourned to Skansen, an open-air museum, which contains a unique collection of objects, showing life in various parts of Sweden and at different periods of her history. Here a charming exhibition of national dances and folk-songs was given by men and girls from the different provinces of the kingdom, all dressed in the typical peasant-costumes of their localities.

Visit to the Mines of the Arctic Circle.

Prior to the general gathering at Stockholm a limited number of the members of the Institute were kindly invited by the Gellivare Mining Company to visit their iron ore mines at Gellivare, the deposits at Kiirunavaara and Luossavaara, and the ore-dressing plant at Luleå. The party consisted of the following gentlemen: Mr. William Whitwell (Hon. Treasurer), Mr. H. Bauerman, Mr. G. R. Dunell, Mr. H. G. Graves, Mr. W. R. Hay, Mr. J. R. Jefferies, Mr. D. A. Louis, Mr. J. de Lazurtegui, and Mr. H. G. Turner. Mr. Otto Broms, the engineer of the company, accompanied the party from start to finish, and with him was Mr. John Hammar, managing director of the De Laval Svea Glowlamp Company, Ltd.

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24th. It had been intended that the return should be made by steamer on the Gulf of Bothnia and the Baltic, but the weather had been so uncertain that in view of possible delay the train journey was considered preferable.

At the station the party was greeted by Consul G. E. Broms, managing director and chairman of the company, and was entertained at dinner at Hasselbacken before the members separated to prepare for the reading of papers.

Throughout the journey, which lasted eleven days, no pains were spared to make the visit successful. In the far north the country had to be scoured far and wide for boats, carriages, and food, but Mr. Bruno Lomm, the head of the police in that vast district, accompanied the party, and was always to the fore night and day. Mr. Hammar was the life and soul of the party, besides being a most successful "Kodak-fiend," and the numerous engineers and managers of works, most of whom spoke most excellent English, gave every information in their power. To Mr. Otto Broms the success of the trip may indeed be said to be mainly due, for his imperturbable good nature, kindly consideration, and great forethought for all things great and small, never once failed in the slightest degree, even in the most anxious moments, during this unique, instructive, and pleasant journey.

Northern Excursion.

After the meeting a limited number of members were invited to visit the mines and works.

The first excursion, which followed the Iron and Steel Institute meeting in Stockholm, was devoted to visiting mines and works north of Stockholm. Fifty members, including Mr. E. P. Martin (the President), Sir James Kitson, Bart. (Past President), Mr. E. Windsor Richards (Past President), Mr. W. H. Bleckly (Vice-President), and Mr. Bennett H. Brough (Secretary) left Stockholm on Sunday, August 28, in a special train of Pullman cars, and in three days visited Grängesberg, Domnarfvet, Falun, Hofors, Sandviken, Forsbacka, Skutskär, and Dannemora, the total distance covered being 425 miles. During the whole time the members were entertained with lavish hospitality at breakfast, luncheon, and dinner by the various companies, who threw their works open to inspection in the most liberal manner possible.

The following was the programme of the excursion :—

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[redacted]

10 A.M.—Departure from Skutskär.
11.55 A.M.—Arrival at Dannemora.
12 to 1.30 P.M.—Visiting the Dannemora Mines.
1.30 P.M.—*Déjeuner dinatoire*, by invitation of the owners of the Dannemora Mines.
3.35 P.M.—Departure from Dannemora.
7 P.M.—Arrival at Stockholm.

The trains for this excursion were placed at the disposal of the members by the courtesy of the Government Railway Administration, and of the Oxelösund-Flen-Westmanland, the Örebro-Köping, the Central Swedish, the Bergslagerna, the Gefle-Dala, and the Upsala-Margretehill Railway Companies.

The distances travelled were as follows:—

	Miles.
Stockholm to Grängesberg	189
Grängesberg to Domnarfvet	41
Domnarfvet to Falun	14
Falun to Hofors	23
Hofors to Sandviken	20
Sandviken to Forsbacka	1
Forsbacka to Gefle	14
Gefle to Skutskär	10
Skutskär to Dannemora	40
Dannemora to Stockholm	73
Total	425

When the train drew up at Grängesberg early in the morning of August 29, it was seen that the station was decked with the Swedish and British colours, and along the route leading to the manager's house, where breakfast was served, there were Venetian masts, bunting, and fir-branch decorations. The band played during the morning meal, which was served by girls in the national costumes, and the toasts usual on such occasions were drunk with enthusiasm, which served to keep the guests warm, for the morning was raw and misty, and the overflow of visitors, whom the manager's dining-room could not accommodate, breakfasted *al fresco* on the balcony. The various mines were inspected, and in honour of the visitors a salute of 100 dynamite cartridges was fired.

From Grängesberg the party proceeded by train to the Domnarfvet

[illegible] works, belonging to the Stora Kopparbergs Co., whose [illegible] served in the Swedish manner in the hall of the Workingmen's [illegible]. The hall was beautifully decorated, a large portrait [illegible] Oscar, surmounted by a trophy of flags and greenery, and a [illegible] of shields bearing the company's ancient [illegible] being [illegible] conspicuous features of the ornamentation. After luncheon [illegible] were inspected. Everything of interest was shown. A triumph[al] [illegible] of iron girders was erected at the entrance, and a guard of hono[r] [illegible] welcomed the visitors.

[illegible] day's proceedings terminated with a banquet given in the [illegible] of the Company's House, which is provided with a fine [illegible] decorated in the [illegible] of the first half of [illegible] century, including a large series of portraits of [illegible], and of the royal personages who have honored Falun [illegible]. These are extremely interesting, although more on histor[ical] [illegible] artistic grounds. The Governor of the Province, and [illegible] men from the district were invited to meet the [illegible] guest was provided with a very artistic menu hand-painted [illegible].

Tuesday morning was devoted to a visit to the ancient copper [illegible] is now 1300 feet deep. The underground workings are [illegible]

After visiting the mines, the members were entertained at a banquet in a hall tastefully decorated with flags and shields of the various iron-brands of the users of Dannemora ore. At 3.35 P.M. the party left Dannemora, and punctually at 7 reached Stockholm, bringing with them most pleasant recollections of a trip that was alike instructive, enjoyable, and successful in every way.

Western Excursion.

The members of the second group left the central station at Stockholm punctually at eleven o'clock in the evening of Sunday, August 28th. Like the first group, which had left twenty minutes earlier, they were accommodated in a long special train made up of sleeping-waggons. The party included Mr. W. Whitwell (Hon. Treasurer), Mr. G. J. Snelus (Vice-President), and Mr. Beardmore (Member of Council).

Early in the morning of Monday they arrived at Laxå, and were entertained at breakfast at the Station Hotel by the invitation of the Laxå Bruks Aktiebolag. Two hours were then devoted to seeing the cellulose works and the ironworks of that company under the guidance of Mr. Carl C. Lindberg, the managing director. The train then went on to Degerfors, where the iron and steel works of the Strömsnäs Jernverks Aktiebolag were shown by the managing director, Mr. Ernst Odelberg, and lunch, by invitation of the company, was partaken of. At these works it was arranged to tap three open-hearth furnaces simultaneously, and the feat was accompanied with great success, the white hot metal bursting forth from all at the same moment as if the men had been moved by clockwork. Another short railway journey took the party to Bofors, where the extensive iron and steel works and the ordnance factory were inspected. Mr. G. Dyrssen and Mr. A. Silfversparre here took the members round and showed them a magnificent spectacular display in the operation of quenching a six-inch gun-tube, with all its accompaniment of boiling oil flaming fifty feet high and more. The guests then dressed in the train and made their way through an exceptionally heavy hailstorm to the house of Mr. G. Dyrssen, where they were received by himself and his wife, and were entertained at dinner by the Aktiebolag Bofors-Gullspång.

After this pleasant function the train left for Filipstad, arriving there about midnight, naturally with most of the guests comfortably asleep in their berths. It came out next morning, however, that the ever-thoughtful hosts had arranged for supper and beds in the hotel for any one who preferred not to sleep in the train, but that, owing to an oversight, this had

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10.30 A.M.—Departure from Laxå.

11.15 A.M.—Arrival at Degerfors.

11.15 A.M. to 12.45 P.M.—Visiting the Degerfors Iron and Steel Works.

12.45 P.M.—Lunch, by invitation of the Strömsnäs Jernverk Aktiebolag.

2 P.M.—Departure from Degerfors.

2.45 P.M.—Arrival at Bofors.

2.45 to 5.15 P.M.—Visiting the Bofors Iron and Steel Works and the Bofors Ordnance Factory.

6 P.M.—Dinner, by invitation of the Aktiebolaget Bofors-Gullspång.

8.15 P.M.—Departure from Bofors.

11.40 P.M.—Arrival at Filipstad.

Tuesday, August 30.

8 A.M.—Breakfast.

9 A.M.—Departure from Filipstad.

11 A.M.—Arrival at Hagfors.

11 A.M. to 1 P.M.—Visiting the Hagfors Iron and Steel Works.

1 P.M.—Lunch, by invitation of the Uddeholms Aktiebolag.

2 P.M.—Departure from Hagfors.

Stoppage at Råda, for visiting the cellulose factory of that place.

3.45 P.M.—Arrival at Munkfors.

3.45 to 5.15 P.M.—Visiting the Munkfors Iron and Steel Works.

5.30 P.M.—Dinner, by invitation of the Uddeholms Aktiebolag.

7.30 P.M.—Departure from Munkfors.

10.50 P.M.—Arrival at Filipstad.

Wednesday, August 31.

8.30 A.M.—Breakfast.

10.40 A.M.—Departure from Filipstad.

11.18 A.M.—Arrival at Nykroppa.

Visiting the Nykroppa Iron and Steel Works.

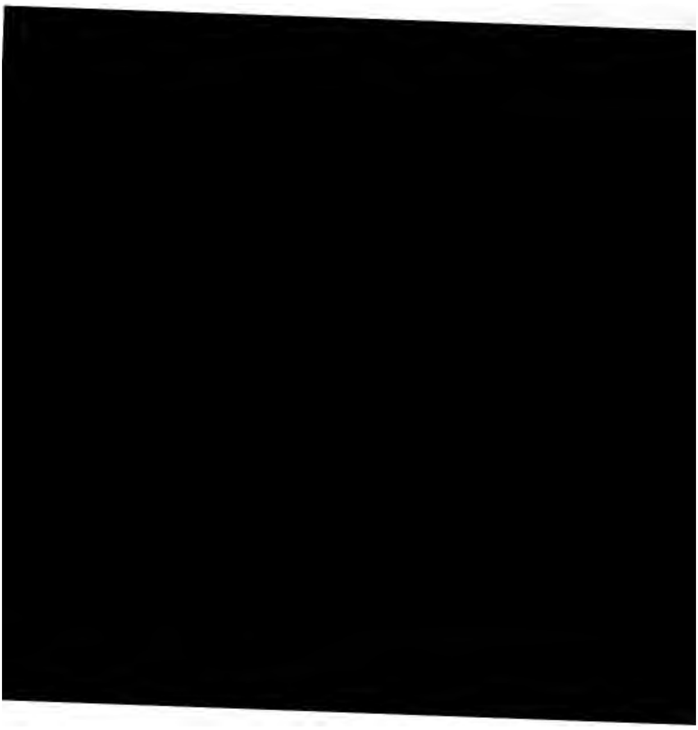
Lunch, by invitation of the Storfors Aktiebolag.

3 P.M.—Arrival at Persberg.

3 to 5 P.M.—Visiting the Persberg Mines.

5.30 P.M.—Dinner, by invitation of the Persbergs Grufve-Aktiebolag.

8.16 P.M.—Departure from Persberg.



in 1887–1888 by Colonel C. O. Bergman, who transferred them to Aktiebolaget Gellivare Malmfält, a company founded in 1890 by Consul G. E. Broms, who is still the managing director and principal shareholder of the company. In order to acquire for Aktiebolaget Gellivare Malmfält the control of the mines at Luossavaara-Kiirunavaara, Consul Broms bought in 1892, for the account of the company, three-fifths of the shares in the latter mines, and he has since uninterruptedly worked on the realisation of the railway connection from the mines to Ofoten. In the spring of 1898 he at length attained this aim, when the Swedish Riksdag and the Norwegian Storthing decided on the construction of the Ofoten railway, which commenced this summer. This decision was preceded in 1897 by a thorough examination of the mines at Luossavaara-Kiirunavaara by means of diamond borings, and the results are given in the "Memorial to the King from the Royal Swedish Board of Trade," and also in Mr. H. Lundbohm's paper in the present volume. The ore from the Gellivare mines is now universally known, since the export of it to Germany, England, Belgium, and France has of late years increased in a remarkable manner, as is shown by the following statistics :—

	Tons.
1892	139,194
1893	260,754
1894	525,728
1895	384,007
1896	614,262
1897	815,797
1898	820,000 (estimated).

The top of the hill in which the Gellivare deposits are contained is 617 metres above sea-level, and 200 metres above the station of Malmberg, from which the ore is despatched by railway. The ore occurs as bed-like masses or lenses in great numbers, of which the most important are those close to the railway station, containing the Hertigen, Kings, Kapten, and Fredrika mines, and those at the top of the ridge, where the Oscar, Sophia, Uppland, Josephina, Skåne, Hermelin, Linné, and Välkommen mines are worked. The ore-bodies all dip to the south, and have inclinations ranging from 50° to nearly vertical. All the mines above mentioned are worked by the Gellivare Company, but there are other and smaller deposits in the neighbourhood, of which one to the east is worked by Witkowitz.

All the power required at Gellivare is generated at a central electric station by continuous-current dynamos made by Siemens & Halske, and driven by inverted compound condensing-engines, made by the Atlas

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through hard gneiss and granite at a rate of 32¾ feet per month with hand-drilling and dynamite. Steel-built side-tipping trams are used for carrying the ore. They hold 3½ tons of ore or 2½ tons of rock. They are made up into trains of six trams each for haulage. The rails are of flange section, weighing 19 lbs. per yard, and are spiked to wooden sleepers.

The sizing and sorting house, to which the trams are run from the Hermelin Tunnel over a trestle, is a wooden covered-in building containing six stalls. Two of these are arranged so that the run of the mine can be loaded direct into the railway waggons if required, as the top screen is prolonged by a shoot. Each bay contains two fixed-bar screens sloping in opposite directions, and placed one over the other. Rectangular bars or rails, spaced 4 to 6 inches apart, are used in the top screen, and rectangular bars, ¾ to 1½ inch apart, in the lower screens. The slope is about 30°. Large ore is thus delivered on one side of the house on to a platform, where it is sorted out by men into trams standing on rails at right angles to the platform, and run over turnplates on to a line parallel with the edge of the wharf. On the other side the middle-sized ore is received on a platform and loaded into trucks running on the wharf on that side. The small ore is collected in hoppers, which discharge into trams running on two lines of rails through the centre of the house, and also leading to the wharf. Three sizes are thus made, but extra screens can be put in to make a fourth size. Five grades of ore are sorted out, and are known as A, B, C, D, and E, according to their percentage of phosphorus (the A grade containing the least), but it is seldom that the ore falls into more than three qualities, so that the handling at the sorting-floor thus arranged need not be excessive. Another form of sorting-floor without any screening arrangement was seen at the bottom of the incline leading from the Välkommen Mine. This incline is at right angles to the loading-wharf, on to which the trams can be led direct by means of curves, or they may be discharged on to a sorting-platform parallel with the rails of the incline. A line of rails parallel to this platform is connected with the rails on the wharf by a turntable. It is, however, a very general custom to sort the ore in the mine before loading.

The ore is worked in open quarries or in underground workings. At present the bulk is obtained by the former method. All the boring is done by hand, and it is considered that, under the present circumstances, this method is preferable to machine-drilling, though in some quarters a determination is expressed to have recourse to rock-drills in

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and Co. This staith consists of an elevated wood trestle with a lift at each end, one for raising three loaded trucks, and the other for lowering the empties. Each lift is worked by two rams with hydraulic pressure of 560 lbs., supplied by a compound pumping engine of 120 horse-power. The trestle is, unfortunately, too far from the edge of the wharf to allow of a direct shoot being used, as the ore will not run at an angle of less than 33°, so the railway waggons are discharged through their bottom doors into an intermediate tipping-waggon which runs at right angles to the wharf, and empties the ore into the shoots. Oscillating three-cylinder hydraulic motors drive the chains by which the railway waggons and the intermediate waggon are shifted, and locomotives shunt the waggons on the ground level. The second staith on the south was built by the present company, and consists of an inclined trestle with a gradient of 1 in 50, up which the loaded trains are pushed by a locomotive. It carries two counterbalanced shoots, which are spaced so that two waggons can be discharged simultaneously into two holds in the vessel. With this plant 10,000 tons can easily be loaded in the day. and the record up to the present has been 78,000 tons in one week.

Magnetic-Separation and Phosphate Works.

The magnetic-separation works, and the works for the production of phosphate for agricultural purposes from the apatite separated from the ore, lie on the east of the shipping-wharf. The power-station contains five tubular boilers supplying steam to four compound vertical engines of 250, 100, 50, and 300 horse-power respectively. The two large engines drive two dynamos, which give a three-phase current of 334 ampères at 520 volts each, the current having fifty cycles per second, and being conveyed to the motors about the works by a three-wire system. It is intended to work these dynamos in parallel, and for this purpose the switchboard is to be rearranged. The smaller engines drive four continuous-current dynamos, arranged in a series parallel system in groups of two to give a current of 250 volts. The ore for treatment is delivered from the railway waggons into a pocket, from which it is lifted to a height of 131 feet by an incline laid with four lines of rails and worked by two 15 horse-power electro-motors. It then is passed through a jaw-breaker and a pair of rolls driven by a 35 horse-power electro-motor. From this point to the separators the plant is in duplicate side by side in the same building, and one-half was running at the time of the visit. The ore is dried in inclined revolving cylinders, and then

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whilst the other three buddles are used for the fine slimes, the shaking-tables for slimes, and the jigs are used for the apatite brought direct from the separators. The washed apatite is dried in a long revolving cylinder, ground and mixed with 30 per cent. of its weight of sodium carbonate in ball-mills of different types, and then fritted at about 1000° C. in double-bedded calcining-furnaces.

The material obtained is a semi-glassy, bluish-grey clinker, and may be considered as a mixture of neutral silicate of potash, soda, and alumina, and a tetracalcic phosphate in which one-sixth of the lime has been replaced by soda. It contains about 25 per cent. of phosphoric acid, of which 96 per cent. is soluble in citrate, and is therefore considered as available for manurial purposes. The clinker is ground to fine powder in ball-mills before it is sold. The furnace-house contains three furnaces, but two more are being built, and though the plant has only been running three months, several hundred tons of the ground material has been made.

The Grängesberg Iron-Mines.

These mines, which are now the most productive in the country, giving nearly one-third of the whole annual produce of Sweden, are situated about midway between Stockholm and the Norwegian frontier, in a slightly undulating gneiss and granite country, about 1000 feet above the sea-level. The deposits, which include both specular hæmatite and magnetite, occur in numerous detached lenticular masses in three lines, which are roughly parallel to the foliation or banding of the crystalline rocks forming the country, and extend for about two and three-quarter miles, with a maximum breadth of about a quarter of a mile.

The general direction is about N. 30° E., with a S.E. dip of 70° or more. Mining operations date back to the beginning of the seventeenth century, and an enormous number of small workings have been opened over the entire district; but the most important deposits, which are those belonging to the easternmost or upper series, were for a long time practically abandoned, their working being forbidden on account of their highly phosphoric character, and it is only since the discovery of the basic method of steel-making, in 1879, that they have been brought into value, an important export trade with Germany, which has developed since 1893, having increased the output to nearly 660,000 tons, about five-sixths of which are exported, while about 80,000 tons are smelted at the Domnarfvet and other works in the neighbourhood. The portion

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gawntrees over the railway lines, where it is discharged into the trucks, which carry it into the shipping port of Oxelösund, on the Gulf of Bothnia, about 60 miles south-west of Stockholm, a distance of about 160 miles. The average amount of rock and ore lifted per pound of dynamite used is about 6 tons. Up to the present time hand-boring alone has been used; but machine-borers, driven by compressed air, are about to be used on a large scale, as trials of electric-borers made last year did not give satisfactory results. The compressor is of compound construction, and driven by an electro-motor. The mixed small ore and waste is sized upon gratings and rotary drum sieves, varying from 2¾ inches to ½ inch aperture, a jet of water being used with the latter to remove small dirt. The larger-sized lumps rejected by the first screen are picked by hand, and the two intermediate sizes are passed over Wenström magnetic separators, which take out the magnetite, but pass hæmatite with the waste, which is, therefore, further hand-picked. The small stuff washed off by the jet is collected in pits, giving a finely-divided product, for which at present no use has been found, although it contains from 50 to 60 per cent. of iron. Probably it might be employed as fettling for puddling furnaces, if it could be obtained at a reasonable price, in English works. About 350 tons of mixed stuff are treated in the separating plant daily, giving about 200 tons of clean 60 to 62 per cent. ore, 50 of powdered ore, and 100 of waste.

Among the most interesting features of the surface arrangements at Grängesberg are those for distributing power, which is entirely derived from water-wheels. As there are no very marked differences in level in the country adjacent to the mines, storage reservoirs covering a large area, with about 22½ miles of distributing leats, have been established for the supply of overshot wheels, averaging 15 to 20 horse-power each, the power being conveyed to the hoisting and pumping gear by the method of travelling rods, introduced into the Swedish mines by Polhem, at the end of the seventeenth century, and in use ever since. These consist of parallel wooden rods, suspended at short intervals upon double-armed iron brackets, which oscillate about fixed centres, moving backwards and forwards at each revolution of the water-wheel, with a perceptible groan at each change of stroke. Iron bell cranks, moving in the horizontal plane, are inserted in the lines where branches are to be taken off, and in this way the western side of the mines is covered with a perfect labyrinth of red-painted posts and rods, the total length of those aboveground being about 24,000 yards. On the eastern or export side of the field, however, electric power is used, obtained from a fall of

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The Domnarfvet Steelworks.

The Stora Kopparberg Company is the oldest industrial corporation in the world, the foundation of its business going back to the first half of the thirteenth century, the period of the discovery of the great mass of pyritic copper ore adjacent to the present town of Falun, and although the date of the actual beginnings are not known, a Royal Charter confirming their then ancient privileges in the year 1347 is preserved at Falun; and a still older deed relating to the exchange of one-eighth part of a share for two estates by the Bishop of Westerås in 1288 has been found in the National Archives at Stockholm. The conventional division into quarter-parts, which were increased from a total of 320 to 1200 in 1616, was continued down to 1888, when the present joint-stock company was organised with a capital divided into shares of the nominal value of 1000 kr.—about £56—each, eight shares being allotted to each original quarter-part, giving a total nominal capital of 9,600,000 kr.—£540,000—the actual market value is, however, much higher, the 1000 kr. shares commanding a price of 3800 kr., the stock being widely distributed through all classes of the community, from the King downwards, but the holdings are entirely confined to persons or corporations of Swedish nationality. The seat of the directorate is at Stockholm, but the business offices are at Falun, which is also the residence of the managing director, Mr. E. J. Ljungberg. The original business of the company, copper mining and smelting, although still carried on at Falun, is now completely subordinate to the other branches, namely, iron smelting, commenced in 1735; and wood-sawing and conversion, which have been carried on since 1643, the last being the most important, as the works on the coast are supplied with logs for conversion from an area of 1235 square miles of timber lands belonging to the company on the Dala River and its tributaries, a drainage system of about 1750 miles total length. Iron-making, which, following the custom of the country, was formerly very much scattered, the furnaces and forges being placed wherever water-power or fuel supplies could be obtained, has now been almost entirely concentrated at a single large establishment at Domnarfvet, about fourteen miles from Falun, where the river channel is obstructed by a ridge of rock, giving a fall of 18 feet to 20 feet. Saw-mills have been worked at this place, on the left bank of the river, since 1643, but the power on the opposite side remained unutilised until 1873, when a portion of the stream above the rapid was deviated by a tunnel about 1000 feet long and 23 feet in diameter,

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that obtained from wood charred in piles, and the labour cost is reduced by two-thirds. There are eight groups of kilns in the cooling yard, adjoining the saw-mills, placed about 250 yards from the left bank of the river, each having its own ropeway carried upon high trestles, which brings the wood from the timber pond, and delivers it at the top of the kiln. The charcoal, when drawn, is loaded into iron buckets and carried by other ropeways crossing the river to the tops of the blast-furnaces on the opposite bank, with a minimum of breakage. The capacity of this plant is 120,000 cubic metres of charcoal per annum, in addition to which storage is provided for 70,000 cubic metres in the coal-house at the works, and 60,000 more in other places up the country. From 7 to 8 cubic metres go to the ton of charcoal. The blast-furnace gas burned in different parts of the works is considered to be equivalent in heating power to 14,000 tons of coal annually.

The Bessemer works, which were reconstructed in 1890, are at a short distance from the blast-furnaces, the charge being brought in a ladle by a travelling crane. There are five converters, two ganister-lined, taking six tons, and three basic-lined for 5-ton charges, the pits being equipped with centre ladle and ingot cranes in the original fashion. The annual production is from 30,000 to 35,000 tons of ingots, about 7000 tons of phosphate slag from the basic, and 1000 tons of manganiferous slag from the ganister-lined converters. The latter, which is essentially bisilicate of manganese, often having the characteristic pink colour of the natural mineral Rhodonite, is returned to the blast-furnaces to recover the manganese. The open-hearth plant includes four 15-ton furnaces, two with basic and two with siliceous lining, with four coal-fired producers, and a steel foundry, the cranes and other machines being driven by electric motors. The rolling-mills, contained in a building covering nearly 3½ acres, whose longer axis is parallel to the direction of the tunnel supplying power-water to the turbines placed in pits below, include a cogging-mill for 1-ton ingots, rail, and heavy bar-mills, two medium and one small train, a continuous wire-mill, three universal mills, and plate and sheet mills. There are nineteen heating furnaces, mostly of Ekman's pattern, each having its own gas-producer, fired with coal, and forced draught. The ingots are reheated for cogging in pits, heated with blast-furnace gas. The larger mills and blowing-engines are driven by bevel wheels from the top end of the turbine-shaft. The accessory machines, saws, shears, travelling cranes, &c., as well as the blowing-fans for the gas-producers, are served by electro-motors, of which there are about forty in use. The twenty-four

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Falun Copper Mine.

The old copper mine, which is about a mile distant from the town on the west side, is still in operation, if only on a reduced scale, after nearly 700 years of working. The deposit, an irregular mass of cupreous iron pyrites, about 650 feet long and 500 feet broad at the surface, diminishes rapidly in depth, and appears to wedge out in depth, the ground having been tested by a diamond boring down to 1345 feet below the surface. For several centuries the working was carried out in open cast, followed by large irregular pillar workings underground, resulting in heavy falls that have, since the end of the seventeenth century, formed a great surface pit about 250 feet deep and fifteen acres in extent. At the present time the working is carried on in the broken ground about 980 feet deep by a system of square work, the space left by the removal of the mineral being stowed with broken rock. The ore is raised by vertical shafts placed at intervals round the rim of the great pit; the deepest is King Frederik Shaft, going down to 925 feet. The principal winding shaft is fitted with a double-bucketed overshot wheel about 50 feet high, with a spiral rope drum having a maximum diameter of about 16 feet; a remarkably fine piece of construction, but almost entirely in wood. Adjoining the main pyritic mass the ground has been broken by diorite dykes, with the formation of a series of small quartz lodes, with pyrites and selenide of bismuth, which contain a notable quantity of gold, the present yield being from 2000 oz. to 2500 oz. annually. The produce of the mine is classified into—(1) Hard ore, essentially copper pyrites and quartz, with 3·5 per cent. of copper, 12½ dwt. of silver, and 2½ to 3 dwt. of gold per ton; (2) soft ore, a cupreous iron pyrites with 1 per cent. of copper, 7½ dwt. of silver, and 15 grains of gold per ton; (3) gold ore or selenium ore, which is hard ore with some selenide and sulphide of lead and bismuth and native gold, containing from 6 to 12 grains of gold per ton; and (4) iron pyrites, with 40 to 45 per cent. of sulphur. The hard and soft ores are mixed and washed in heaps. The burnt ore, containing about 2·5 per cent. of copper, is mixed with 14 per cent. of salt, ground in a ball mill, and subjected to a chloridising roasting in a reverberatory or rotating calciner, followed by extraction with water and sulphuric acid, and precipitation of the metals contained in the liquor by scrap iron. The spent liquor and the exhausted ore are thrown away; the latter contains about 0·16 per cent. of copper, showing an extraction of about 94 per cent. of the total copper contained. The precipitate containing 85 per

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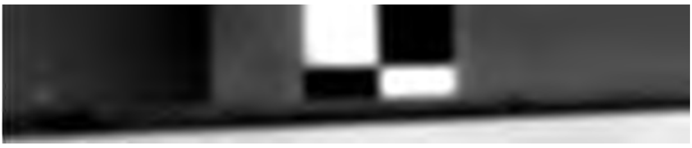
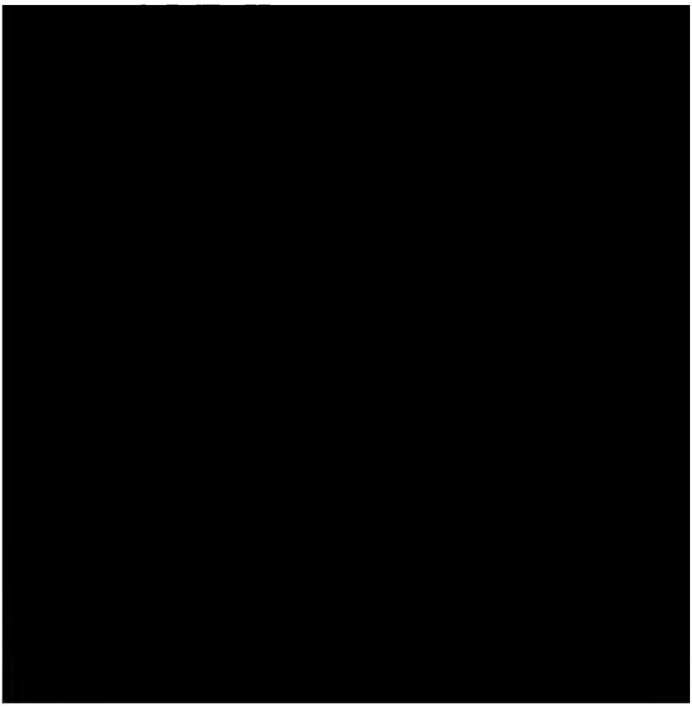
and water-power hammers, and their necessary auxiliary machines. A tall warehouse-like building covers the blast-furnaces, and is connected by an inclined tramway carried on tall trestles, with the charcoal-house on the right, while the smaller buildings with chimneys adjoining, contain the Westman calcining kilns, which are supplied with ore by skips running on steep inclines, leading from the ore yard on the railway. The ores, following the usual Swedish practice, are subjected to a very thorough calcination, attended in the case of magnetic ores with partial fusion, in order to ensure the complete removal of sulphur; and when cooled and crushed to about 1 inch lumps are lifted by an elevator to the platform at the furnace top, which is of considerable size, on account of the large number of different minerals used. These are partly obtained from Nyangs and Penning mines, in the immediate vicinity, but to a large extent from other places within a radius of about fifty miles, especially Norberg and Bispberg; and, as will be seen from the following analyses, their waste matter is partly basic and partly siliceous, so that by judicious mixing the use of limestone flux may be reduced to a minimum. All, however, are exceedingly pure as regards sulphur and phosphorus.

Mines.	Fe_3O_4	Fe_2O_3	MnO	CaO	MgO	Al_2O_3	SiO_2	P_2O_5	S.	Fe.	P.
Nyangsgrufvan .	88·77	1·00	0·26	3·20	0·56	0·20	7·60	0·005	0·028	64·26	0·002
Penninggrufvan .	52·07	14·73	20·18	1·77	1·34	1·06	6·74	0·007	0·024	48·02	0·003
Myggbogrufvan .	79·17	0·14	0·37	2·84	4·86	0·47	8·95	0·007	0·006	57·43	0·003
Göskgrufvan . .	90·03	0·83	0·20	1·20	0·07	0·10	7·52	0·007	0·008	65·84	0·003
Kolningberg . .	71·44	2·82	4·43	1·36	3·45	0·98	2·66	0·005	0·008	53·92	0·002
Gröndal . . .	76·13	5·11	4·46	1·30	1·73	0·34	2·68	0·009	0·005	59·12	0·004
Bispberg . . .	95·41	2·30	0·35	1·40	0·79	0·11	0·40	0·010	0·006	70·70	0·0045
Limestone . .	...	...	...	54·60	0·42	1·54	1·65	0·005	...	...	0·002

One furnace is worked with an open top, the other is closed by Tholander's charging apparatus, which is similar in principle to the divided bell at one time used in America, having a central tube and bell for the fuel charge and an outer annular one for the burden. The central bell is first dropped to admit the charcoal, and is then followed by the outer one, which delivers the charge around the wall of the furnace as nearly as may be in the manner of hand charging. The operations are made consecutive by an arrangement of taut and slack chains worked from the same lever. The blast, at about $1\frac{1}{4}$ lb. pressure, is heated by pipe stoves to about 300° C. The annual make of the two furnaces is given as 11,000 tons of pig iron, or about 110 tons per week each, partly manganiferous, with nearly 1 per cent. of silicon





advantage at the higher, and the latter at the lower tempers. The corresponding variations in composition are rather curious :—

Carbon.		Manganese.	Silicon.	Phosphorus.
0·10	Bessemer	0·16	0·008	0·028
	Open-hearth	0·30	0·005	0·015
1·30	Bessemer	0·40	0·048	0·020
	Open-hearth	0·50	0·080	0·024

The products of Hofors are largely exported in a partially finished condition, such as blooms, billets, tube, ingots, wire rods, &c., either hammered, pressed, or rolled, the forges and mills being equipped with steam and other hammers, a fine hydraulic press, plant and engines by Messrs. Fielding & Platt, and blooming, billet, bar, and wire rolling mills. The most interesting feature in connection with this part of the works is the extended use in the rolling mills of electro-motors worked by current from a power station about one and a half miles away. The driving power is derived from a head of 100 feet, conveyed partly by an open leat and partly by a wooden tube, following a clearing through the forest of about 800 yards. The tube, about 6 feet in diameter, built of straight 2-inch staves with thicker collars at the joints, hooped with iron and thickly coated with a resinous waterproof varnish, terminates in a heavy stone pier, where it connects with an inclined pipe of smaller diameter, made of riveted steel plates leading to the powerhouse. This contains six turbines with vertical bucket rings, receiving the water at the circumference and discharging through the centre and horizontal shafts, which are coupled directly to the generating dynamos, Four of these are of 300 horse-power, at 480 revolutions per minute, but two of them are constructed on a variable admission principle, having two systems of buckets on the shaft, which can be run together to give the full power, or singly, to give 200 horse-power at 320 revolutions. The remaining turbines are smaller, one of 150 horse-power at 515 revolutions, and one of 40 horse-power at 720 revolutions. Each of the larger turbines works a 300 horse-power triphase alternating dynamo at 900 volts terminal pressure, of the unusually low period of sixteen complete cycles per second, with four cast-iron fixed magnets and a revolving laminated iron armature, 37 inches in diameter and 31 inches long. The weight is about 19 tons. The energy required for exciting the field magnets is 2·7 kilowatts. The 150 horse-power turbine drives a smaller alternator with fourteen poles, giving 900 volts at a frequency of sixty cycles per second, with an exciting energy of 1·5 kilowatts. The 40 horse-power turbine works two continuous current

[illegible], which furnish the exciting current for the alternators, as [illegible] lighting the [illegible] and some private houses. There [illegible] the four 500 horse-power generators are kept at work, the [illegible] kept in reserve. Each one has its own circuit of three [illegible] wires, while a fourth circuit of three [illegible] mm. wires serves [illegible] horse-power generator, the twelve wires being carried on [illegible] by an overhead line [illegible] yards long to the works, [illegible] motors of [illegible] horse-power, each connected with [illegible] larger generators, and taking the current of the original generator, [illegible] work independently, and more than three of them can [illegible] together. Two of the motors are connected with the [illegible] one with the [illegible], and the fourth with the small [illegible]. [illegible] generally similar to the generators, but smaller, having four [illegible] armatures, making [illegible] revolutions per minute.

The starting is done from the power-house, with both dynamos [illegible] and in connection, the field magnets of the generator are [illegible] the motor is attached to the turbine. In this way the starting [illegible] is almost instantaneous, and the motor develops its full load [illegible] the use of a starting resistance. The communication between [illegible] and the power-station is effected by telephone. At the [illegible] of [illegible] revolutions of the generators, and [illegible] of the [illegible] [illegible] efficiency of [illegible] per cent. [illegible]

manufacture of Bessemer steel on a large scale in Sweden. Starting with a single blast-furnace, two converters, two steam-hammers, a tire-mill, and a small roller for tool steel, the principal product being railway tires, other branches of manufacture have been added, and now there are three blast-furnaces, two converters, an open-hearth furnace, lately finished; thirteen steam-hammers, including one of 15 tons and four of 5 tons; ten rolling-mills, a wire-drawing mill, and works for making saws, clock springs, and other hardened, polished articles made from flat steel, a manufacture in which Sandvik takes a leading position in Europe. The ores smelted are similar to those used at Hofors, but have a wider range in composition, the most prominent being the following:—

	Fe_2O_3.	Fe_3O_4.	FeO.	MnO.	MgO.	CaO.
Bispberg . . .	6·98	84·22	...	0·10	1·07	0·58
Tremänning . . .	35·81	29·91	...	0·12	1·24	1·26
Vestra Maus . . .	56·21	18·06	...	0·05	0·29	1·12
Svartvik . . .	...	63·62	6·72	2·43	4·33	7·25
Kolningberg . . .	...	60·13	6·36	4·72	7·58	3·93
Langvik	...	41·83	4·02	8·80	6·55	11·58
Hillang	...	33·63	15·13	15·45	2·69	8·48
Limestone . . .	...	...	0·50	...	0·76	52·48

	Al_2O_3.	SiO_2.	P_2O_5.	Volatile.	Total.	Fe.	P.
Bispberg .	0·21	6·91	0·009	...	100·084	66·42	0·004
Tremänning .	1·09	30·38	0·037	...	99·857	46·73	0·016
Vestra Maus	1·89	22·21	0·034	...	99·915	52·43	0·015
Svartvik .	2·39	8·21	0·010	5·38	100·369	51·30	0·004
Kolningberg .	6·02	6·50	0·005	4·52	99·795	48·83	0·002
Langvik .	1·76	5·93	0·016	17·50	98·046	33·42	0·007
Hillang. .	2·14	12·61	0·015	7·80	98·062	36·12	0·007
Limestone .	0·51	3·00	0·009	42·07	99·329	...	0·004

The smelting and Bessemer converting are conducted much in the same way as described above. Ingots for tires are cast in covered moulds, and those for rolling in open ones, which are filled from below from a feeding tube at the side, the moulds being mounted in a rectangular frame running upon wheels, which brings them up in succession to the converter for filling. The new open-hearth furnace is placed at one end of a spacious shop commanded by an electric travelling crane, made by the Shaw Electric Company, of Michigan, and is apparently intended to serve as a steel foundry. The re-heating is done in Ekman gas furnaces, fired by coal and forced draught in the producer, the secondary air being raised to 150° C. by the waste heat of the

[illegible] There is some water-power, but steam is mostly used, [illegible] thirty-five engines, collectively of about [illegible] horse-power, [illegible] being that driving the cogging-mill, a compound of [illegible], with [illegible]-inch high-pressure and [illegible]-inch low-pressure cylinders [illegible] on separate bearings, one being vertical and the other [illegible] but both working on one crank. The mill is a very power[illegible] having three stands of three-high rolls [illegible] inches in diameter. [illegible], however, are the band-rolling mills contained in a [illegible] [illegible] square feet, which was completed in [illegible]. [illegible] a heavy mill with four pairs of [illegible]-inch two-high rolls, [illegible] horizontal rolls in addition, a lighter one with four pairs [illegible] rolls, three with vertical rolls, a wire-mill with six sets of [illegible] rolls, and a tube-mill with five pairs of [illegible]-inch rolls. This [illegible] rolling, that is universal mills, was in use in all the works of [illegible]. The hot-rolled band of No. [illegible] gauge, [illegible] inches wide and [illegible] long, weighing [illegible] lbs., exhibited at Chicago in [illegible] and [illegible] in [illegible], which now adorns the sample-room at the works, [illegible] example in cold-rolling, was one of the best achievements [illegible] mills. The heaviest cold-rolled band of No. [illegible] gauge [illegible] wide and [illegible] feet long, weighs [illegible] lbs., and as a result [illegible] of all has been rolled into a [illegible] inch strip of No. [illegible] [illegible]

Bessemer ingots was 9157 tons in 1897, which were to a small extent exported as such, but the greater part were converted into bars, wires, nail-rods, and tubes, the latter being of specially high quality in regard to toughness and finish. The working details are generally similar to those observed in the neighbouring works, but the blast-furnaces are somewhat larger than usual. One recently lined is, exclusive of a cylindrical part 5 feet high under the charging bell, 44 feet 3 inches high, 10 feet in diameter at the boshes, 5 feet in the hearth, and 7 feet in the throat. Between 14 feet and 24 feet above the hearth level the stack is cylindrical and 10 feet in diameter, which gives a total capacity of 2767 cubic feet. The charging is done with a double bell, similar to the Tholander apparatus.

The Skutskär Saw-Mills.

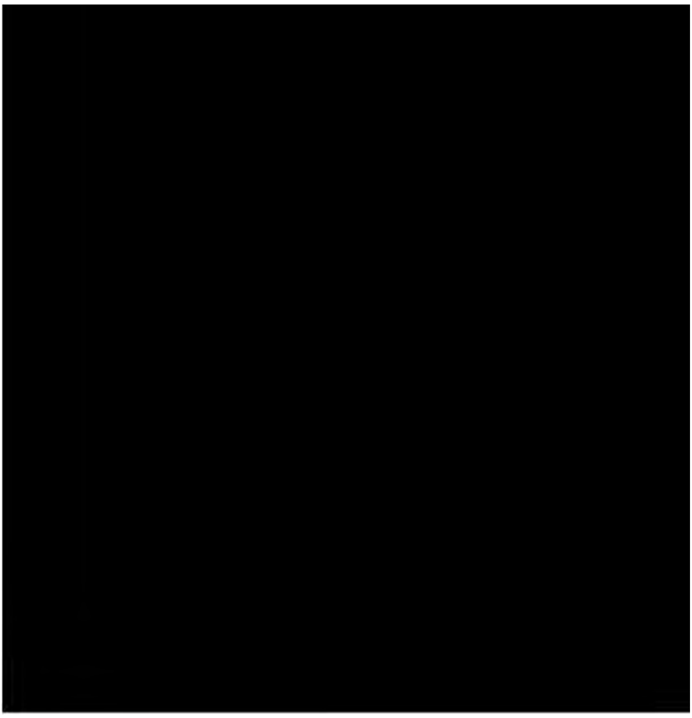
The Skutskär saw and wood pulp mills belong to the Stora Kopparberg Company. Skutskär is a small natural harbour on the Gulf of Bothnia, about ten miles from Gefle, immediately south of the mouth of the Dala River. The first mills on that site, built in 1869–70, and destroyed by fire in 1874, have been rebuilt on an extended scale, and are now the largest establishment of their class in the world, from one to one and a half millions of logs being cut up annually. These are brought from Elfkarleby—where the Dala River is obstructed by a fall of 54 feet—by a canal seven miles in length, to the mill, a large timber-framed building of two storeys. The saws, nineteen single and five double frames, are on the upper floor, with the edging and finishing machinery below. Short ends of planks and other defective pieces, which in former years went for firewood, are now very carefully selected and converted into many smaller articles, such as box boards, building laths, blind rollers and broom handles, and staves for small casks, all of which are turned out finished and ready for use. The best portions of the waste after this selection go to the paper pulp mills; waste ribs and slabs are converted into charcoal, leaving the shavings and sawdust for raising steam.

The annual output is about 57,000 St. Petersburg standards of boards, deals, battens, sawn and planed stuffs, floorings, &c., mostly fir. The deal yards cover about 300 acres, with a wharf formed of loaded crib work of nearly 2000 yards frontage. The finished work from the mills is carried to and from the store-yard by railways worked by electric locomotives; the total length of lines is about 16 miles. Capstans driven by electric motors are also used on the wharf for loading the

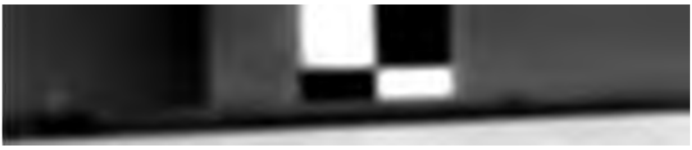
[illegible] which carry the timber to the shipping in the harbour, [illegible] to a depth of 13½ feet. From 600 to 800 vessels, together [illegible] 120,000 tons, are loaded in the year; the largest ship in port [illegible] time was a new iron barque of about 800 tons, belonging to [illegible] order to shorten the time required by seasoning, a method of [illegible] heated dusty air has lately been adopted. This is done in a [illegible] about 120 feet by 73 feet, where the newly sawn stuff, stacked [illegible] piles, is subjected to a rapid current of air heated to about [illegible] the exhaust steam of the mill engines propelled by a fan [illegible] chimney action. About 2½ days of this treatment is sufficient [illegible] the wood to that obtained by six to eight weeks' exposure [illegible] without splitting or warping, in a similar condition. The [illegible] from the saw-mills is carried by the electric railway about [illegible] the [illegible] pulp works, where it is cut and rasped into pieces [illegible] inch long, and passes by a bucket elevator to hopper bins [illegible] floor, [illegible] over a series of steam vessels. In these the [illegible] is disintegrated by boiling under pressure in a solution of [illegible] which dissolves resinous and extractive matters, leaving [illegible] fibre or cellulose untouched. The cleaned fibre when [illegible] diluted in a large quantity of water passed through copper [illegible] and then goes to a continuous paper machine with [illegible]

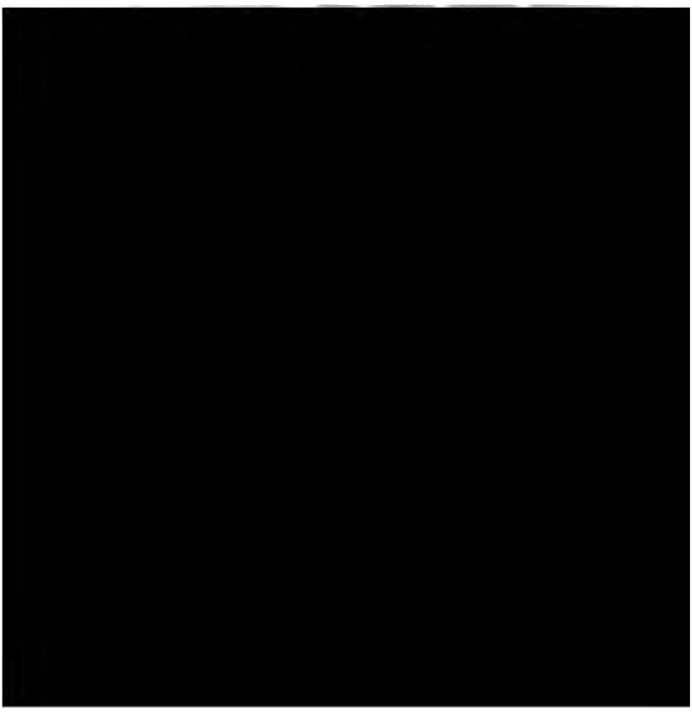
The Dannemora Mines.

These mines, which are remarkable for the excellence of their ore more than for their size, have been worked from a very remote period, and have passed through many different hands. In 1643 they were, together with the associated ironworks in the neighbourhood, purchased by Louis de Geer, who introduced the Walloon forge into Sweden, and the same method of smelting has continued to the present time, the mines being now owned by and worked for the joint account of a body of forge masters, who divide the produce, which is primarily employed for making the highest class of bar iron for conversion into steel by cementation; but as there is only a limited market for this material, about 90 per cent. of it going to Sheffield, the ore is now to some extent used for improving the quality of Lancashire bar iron and Bessemer steel. The mines extend for about 2 miles in length, and 760 yards maximum breadth, the area of the workings being about 125 acres, within which the deposits are scattered about in three principal groups, distinguished as northern, central, and southern fields respectively. At different times about eighty mines have been opened for the surface on the deposits, but only seventeen of these are now actively worked. The largest ore body, that in the central field, extends for about 900 feet in a nearly N. to S. direction, and had a maximum breadth of 150 feet in the higher levels. It is nearly vertical, with a slight westerly dip between walls of grey crystalline limestone, which alternates with bands of compact felstone or hälleflinta, a rock of about the same ultimate composition as a granite, but without any separation into different minerals. Another characteristic associate is a dark-coloured chlorite schist, all these rocks being found at intervals as included masses or sheets, traversing the mass of the ore as well as in the walls. As in most of the historic Swedish mines, the older shallow workings have at different times collapsed with the formation of deep open pits; the largest of these, Stor-Rymningen, covers a large part of the central ore field, and there are others of smaller size in the northern and southern fields. The walls of these pits have on their western sides been carefully dressed square, and lined with heavy masonry for some distance down to prevent influx of water, through the drift covering the surface from the adjacent lake, which runs along the whole extent of the mines. The mining is now done by overhand stoping under a solid covering. In the bottom workings of the central mine, which is 836 feet deep, the deposit, about 50 feet broad, is stoped in lifts of about 15 feet high, the excavation being filled



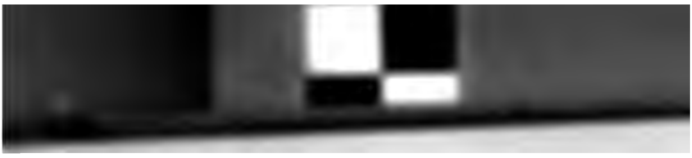
eastward), Gimo, Harg, Löfsta, Strömsberg, and Wattholma, lying within a radius of 20 miles. Skebo, 25 miles south-east; Söderfors and Gysinge, about 25 miles east, on the Dala River; Ljusne, about 70 miles; and Iggesund, 135 miles north, on the Gulf of Bothnia. The last of these is a successor to Forsmark, an establishment that was closed in 1881, when the making of Walloon iron was begun at Iggesund; but Österby, Löfsta, and Gimo were included in the original purchase of the mines by Louis de Geer in 1643. The pig iron intended for the Walloon forge is smelted from the ore previously calcined at a full yellow heat to remove sulphur, without flux, with charcoal and slightly warmed air, from 50° to 100° C., and cast into pigs from 8 feet to 10 feet long, 10 inches broad, and about 4 inches thick in the middle and 2 inches at the ends. The fining process, which is carried on in the original manner, or with very slight alterations, is conducted in two open fires—the "bloomery" and "chafery" of English works in the days preceding Cort's invention of the puddling furnace. The former is a rectangular hearth 18 inches long, 22 inches broad, and 5 inches to 6 inches deep, with a single tuyere sloping about 20°. Pine charcoal is used as fuel, and cold blast at about 2 inches pressure of mercury. When the fire is made up the ends of two of the long pigs of iron are introduced through a notch in the back wall, and melt away gradually before the blast. The metal being almost free from silicon is rapidly decarburised, and stiffens during the melting, so that the working of the iron is begun almost as soon as the hearth is filled, and in about an hour the ball, weighing from 80 lbs. to 100 lbs., is lifted and taken to a tilt hammer of about 6 cwt., and beaten to an eight-sided bloom or piece, which is then brought to a sort of dumb-bell shape by drawing it down in the middle under a steam-hammer, leaving the ends unchanged. A bloom in this condition was formerly known as an Ancony, and the thick ends as Mockit heads; but these terms are now completely obsolete. The corresponding French expressions are *Encrenée* and *Maquette*, which are phonetic variations from a common origin; but whether the English or French represents the original form is uncertain. Each of the heads is reheated in turn in the chafery fire, and forged lengthwise into a bar under the tilt hammer. Usually the first reheating of the bloom is done in the finery fire during the working of the charge of metal, but the practice seems to vary in this respect. At Österby Forge, which was visited by a small number of the party, there are four fires—two for firing and two for reheating, which are grouped in pairs, each pair having a steam-boiler above it fired by the waste flame, for raising steam for the hammers. The making of Walloon iron is

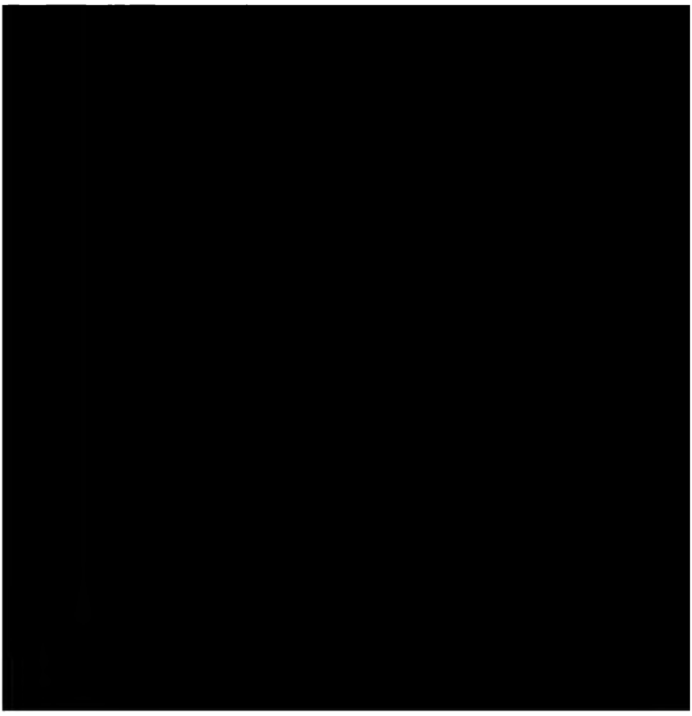




material is made by burning sulphur in a small furnace, cooling the sulphurous anhydride in coils in a water-tank, and then passing it by fans through vertical wooden towers filled with fragments of white crystalline limestone, over which water trickles. A mixture of calcium sulphite and free sulphurous acid, $2CaO,SO_2 + SO_2$, results. The revolving boiling cylinders are built of wrought-iron plates lined with $\frac{3}{8}$-inch lead sheet. Steam is admitted through the cast-iron trunnion ends at a pressure of about 70 lbs. per square inch, and the boilers are slowly revolved at about five turns per minute for fourteen to sixteen hours. The bleached stuff is then very carefully washed and pulped, and any unreduced pieces of wood are separated on shaking screens. The clear white pulp is passed through machinery very similar to that used in an ordinary paper-mill with wire cloth, heated drums, &c., or the loose pulp sheet, instead of being dried by hot drums, is pressed to expel the water. Steam is raised at these works in tubular boilers fired with rough peat and waste wood.

The ironworks are a short distance from the cellulose works, and contain one blast-furnace of which the dimensions are: height 50 feet, diameter at throat 5 feet, at boshes $9\frac{1}{2}$ feet, and in crucible $4\frac{1}{2}$ feet. It has four tuyeres $2\frac{1}{4}$ inches in diameter, and the blast is at a pressure of $1\frac{1}{2}$ lb., and a temperature of 500° C., the heat being obtained from gas-fired cast iron pipe-stoves. As is usual, the blast-furnace is a solid pyramidal stone erection, and the iron is tapped every six hours into cast-iron chill-moulds. A broken pig shows a chill to about half its depth, the upper part being fine grey iron. Analysis shows 0·25 per cent. of silicon, 0·06 of phosphorus and no sulphur, but lower qualities are sometimes made. For the production of a ton of iron 50 hectolitres (or about 16 cwt.) of charcoal is used, and limestone is employed as flux. Wrought iron is made from this metal at a separate works in nine Lancashire hearths. Formerly three men were employed at each hearth, but now the mechanical appliance invented by Mr. Y. Lagervall, and referred to in Mr. Åkerman's paper, is used. In this appliance a ⊔-shaped bar or frame is hinged around the front of the furnace and oscillated by power so that the men can thrust their stirring-rods into the hearths and let them be worked mechanically. This improvement has reduced the number of men required by one-third, and it is also considered to have effected a saving in charcoal. The charge consists of 330 lbs. of iron with 15 to 18 per cent. of its weight of limestone, and 25 hectolitres (or 0·4 ton) of charcoal is used as fuel per ton. A charge is worked through in about an hour, or one hearth with its two



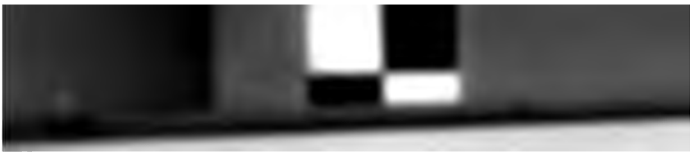


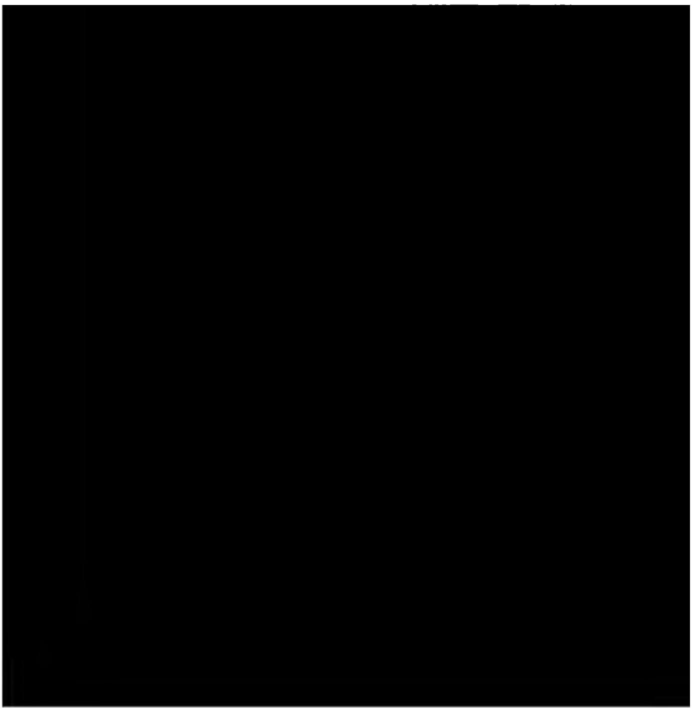
THE BOFORS WORKS.

The works at Bofors include iron and steel works and an ordnance factory. They are situated in the county of Örebro, and belong to the Aktiebolag Bofors-Gullspång, which was established in 1873. As far back as 1646 there were ironworks at Bofors, but they were very small until about 1870, when they were considerably enlarged. At present these works consist of one blast-furnace, with roasting furnace, two open-hearth furnaces, thirteen furnaces for making charcoal blooms, five rolling-mills for bars, rods, hoops, and sheet, together with a steel foundry and the ordnance factory. This company is also in possession of the Björneborg Steelworks, in the county of Wermland, with two blast-furnaces, two Bessemer converters, and a large steam forge. The average production from the company's iron and steel works is about 15,000 tons a year, not including considerable quantities of ordnance material made, not only for the Swedish Government, but also for foreign countries. Heavy guns, up to 10-inch bore, gun-carriages, armour-plates, armour-piercing projectiles, &c., are among the products. The ores smelted are chiefly obtained from the mines of Striberg, Haggrufva, and Persberg.

The blast-furnace, now twenty-five years old, is 56 feet high, 9 feet wide in the boshes, and 4 feet in the crucible. Formerly the blast was heated to 680° C., but this has been dropped to 550° C., as the former temperature was too high to be maintained regularly. Nevertheless, 110 tons of iron are made weekly, with 53 to 60 hectolitres of charcoal per ton of pig, which at the present time is being made with 0·15 to 0·18 per cent. of silicon. The other furnaces owned by the company are a foot larger in both boshes and crucible.

There are two double-hearths for making blooms, and eight mechanically worked single-hearths. The double-hearths do not have the mechanical appliance for manipulating the stirring-rods, but as they are worked from both sides the bloom made is larger. Between each pair of hearths is a charcoal hopper fed from an overhead tramway. Blast is supplied through water-cooled tuyeres, one on each side, at a temperature of 230° C., and the charge of pig is 320 lbs. for single and 380 lbs. for double furnaces. The average production of blooms is 100 lbs. from 116 lbs. of pig, which is pre-heated in the flues at the side or back of the hearth. The lumps are shingled as usual under a tilt-hammer, and are rolled down into wire, flat bars, &c. Most of the rolling-mills are kept on iron as far as possible, and steel is only rolled when there is an excess over the quantity required for castings.





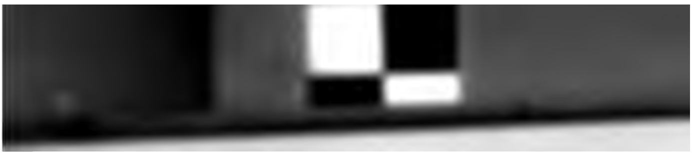
large planing-machines of Swedish manufacture, and a large gun-boring machine is by Greenwood & Batley, of Leeds, who have also supplied a 2000-ton hydraulic press.

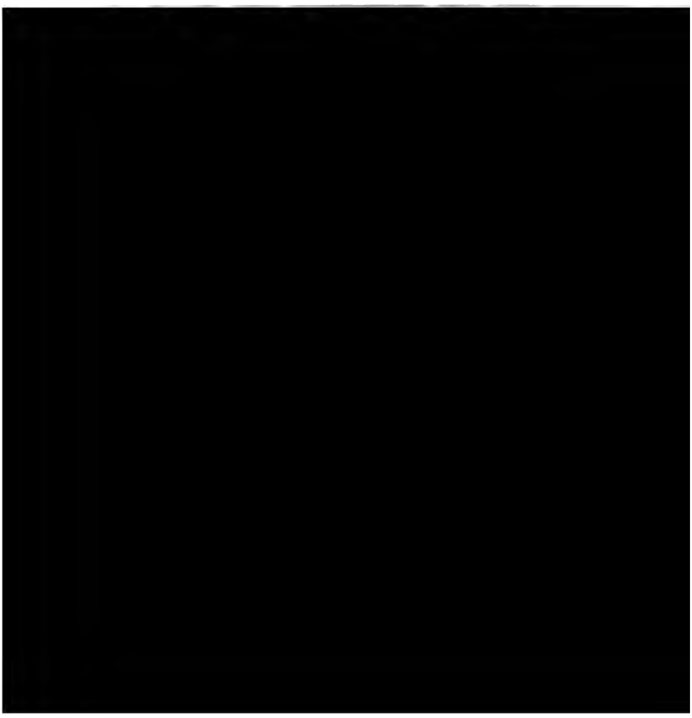
The Uddeholms Company's Works.

The present Uddeholms Aktiebolag started in 1870, on the reconstruction of the previous company, which was founded in 1746. Their estates mostly lie in Wermland, and include an area of 495,000 acres, on which there are some 13,500 inhabitants. About 50 miles of private line on a metre gauge have been built for the company on their land, and afford communication between Filipstad, Hagfors, Råda, and Munkfors. At Råda the company owns cellulose works, and their iron and steel works are situated at Hagfors and Munkfors, where 400 and 600 men respectively are employed. The annual output of iron and steel is 17,000 tons, from ore and charcoal obtained on the estate. About 3000 tons of this product are worked up into finished articles, such as springs, wood-screws, and nails, before it is exported.

The Hagfors Works.

At Hagfors there are two blast-furnaces, two acid Bessemer converters, two open-hearth furnaces, two rolling-mills, a steam-hammer, machine-shops and foundry, and factories for wood-screws and cut horse-shoe nails. Four hundred workmen are employed, and 3200 horse-power is obtained from the waterfalls by turbines. The blast-furnace house is a particularly fine building. It contains two furnaces and two kilns, together with bins for the calcined ore and the ore-breaker, in which the ore is broken to about walnut size before smelting. Each furnace is 56 feet high, 7½ feet at the throat, 10 feet at the boshes, and 5 feet in the crucible. Blast at a pressure of 1½ lb. is heated to 450° C. in pipe-stoves. The charge consists of 15 hectolitres (0·24 ton) of charcoal, which is first dropped through the bell, followed by 680 lbs. of ore, and 140 lbs. of limestone. The ore is calcined for about forty-eight hours to a low, red heat in the kilns by waste gas from the blast-furnace, about 200 tons being treated daily, but these kilns would easily treat 300 tons. On the top of the furnace are small bins for ore and flux, which are weighed out on a steelyard arrangement which runs on a swinging crane-arm, whilst the charcoal is charged direct from the skips in which it is brought up. The steel-making house contains two open-hearths and two converters,



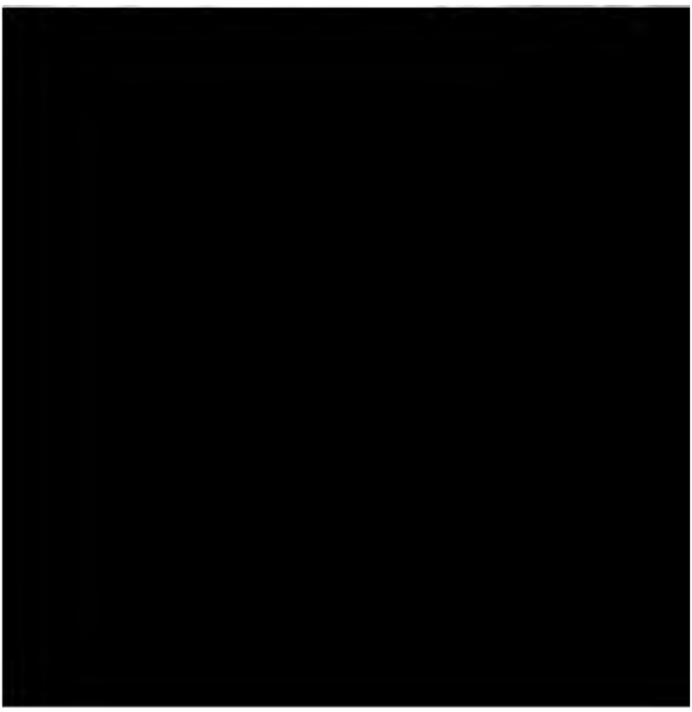


receives the digested material. One very large paper-machine made at Carlstad, in Sweden, converts the pulp into sheets, which, to avoid duty as finished material in Belgium, France, and Germany, have holes torn in them by a toothed roller, placed after the heated drums. The bleaching-liquor is made by passing sulphurous anhydride from burning sulphur through cooling coils into milk of lime contained in large wooden vats. A short length of wire ropeway connects the works with the railway, and, as usual, the mill is driven by turbines. Waste wood is drawn away from the wood-working machinery by fans, and is used for raising steam.

The Munkfors Works.

In the ironworks at Munkfors are two single Lancashire hearths and eight double hearths, all worked by hand. The charges are 286 and 350 lbs. respectively of pig iron, and the loss averages 17 to 20 per cent. in the bloom. About 66 hectolitres of charcoal are used per ton, and this charcoal is washed by dropping it into a water-tank, so as to remove any stones or dirt. The blooms are shingled, as usual, under a tilt-hammer, and part of the billets are drawn down into bars, 2½ by ½ inch, under old-fashioned tilt-hammers, with cams at their sides, for subsequent conversion into blister-steel in two sawdust-fired furnaces in another part of the works. This blister-steel contains 0·025 per cent. phosphorus, 1·0 carbon, 0·005 sulphur, and a trace of silicon. Another portion of this Lancashire iron is rolled into wire rod in a continuous mill. The billets, weighing about 110 lbs., are roughed down to an inch square in seven passes, and then reduced to No. 4½ B.W.G. by ten passes in the finishing-mill and wound on an automatic reel. This mill, working day and night, produces 35 tons of wire rod.

The open-hearth plant consists of one 8-ton and two 5-ton furnaces, in which all the scrap iron is used. The works produce nail and other kinds of steel. In the rolling-mill for merchant steel there is a universal mill, making sizes from 8 by 1 inches to 1 by ¼ inch. Tool-steel bar is made under a pneumatic hammer, supplied by Nedqvist & Holm, Trollhättan. The heating-furnaces for billets are worked in pairs, a preliminary heat being given in the first, whilst the second raises the work to welding temperature. Cooling the furnace by the introduction of cold iron is thus avoided, and the working is more rapid. Wire-drawing and wire-nail making are carried on at these works. A sample of piano-wire (with 0·85 per cent. of carbon) made here shows an elastic limit of 21·6 tons per square inch, an ultimate strength of 54 to 57



works the converters are of 4 tons capacity, placed parallel at the ends of a semicircular pit, commanded by a jib-crane. Amongst other reheating-furnaces in the rolling-mill are two modified Bildt furnaces similar to those seen at Bofors, except that the charging-lift was slightly different, being adopted for heavier work.

The Storfors works make hammered bar iron and steel tubes, according to Mr. R. C. Stiefel's method, the annual production being 3000 tons of tubes.

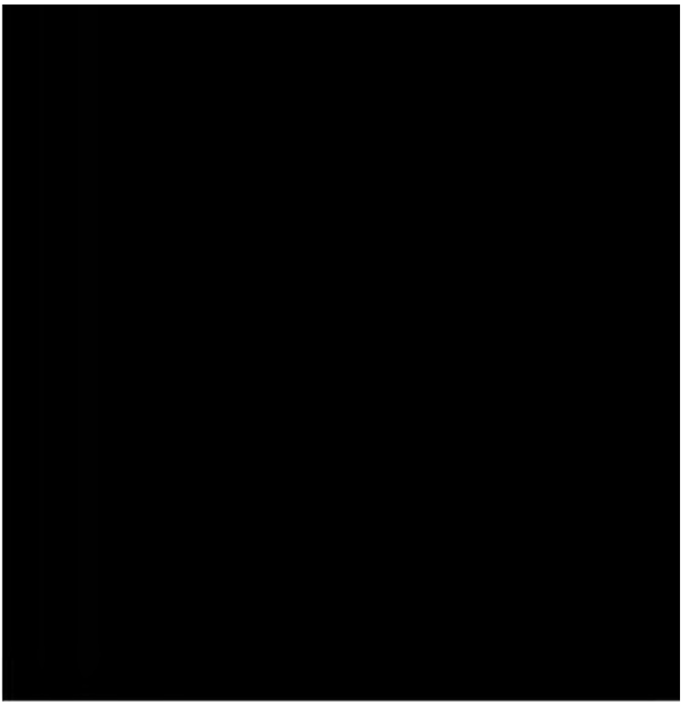
The company also owns two saw-mills, for the purpose of turning to profit the considerable quantities of timber furnished by their extensive forests.

The Persberg Iron Ore Mines.

The Persberg iron ore field is the most important in Wermland. It lies about 4 miles east of Filipstad, and is about 37 miles distant from Kristinehamn by the Mora-Wenern railway. The ore field is about 5 miles long and 2½ to 3 miles in breadth. According to tradition, ore has been worked since the middle of the fourteenth century. The oldest accounts of these mines kept in the "Bergmaster" record office date back to 1658, and state that the Storgrufvan, a great mine known from time immemorial, had been abandoned for sixty-one years, and others for over a century.

The old method of driving by fire setting was kept up here until the beginning of the eighteenth century, when blasting by powder was introduced, and afterwards continued for another century and a half, until superseded in 1865 by nitro-glycerine, the consumption of that explosive being at present some 7 tons a year.

The field belongs to and is worked by the Persbergs Grufve Aktiebolag, the principal shareholders of which own the largest ironworks in the mining districts of Wermland and Karlskoga, and consume all the iron ore that is produced. The ore consists of magnetite, and appears in bent and creased beds in granulite, which forms the country. These iron ores are of the most excellent quality, and have therefore very greatly contributed to the world-wide reputation of Swedish iron. The principal deposits are Odalfältet and Högbergsfältet. The mines which now yield the greatest quantity of ore are named Storgrufvan, Alabamagrufvan, Krangrufvan, Skärstötegrufvan, and Gustaf Adolfsgrufvan. In these mines, together with some others worked to a smaller extent, the ore covers an area of about 5000 square metres, but the ore area of the whole mining field is estimated to amount to about

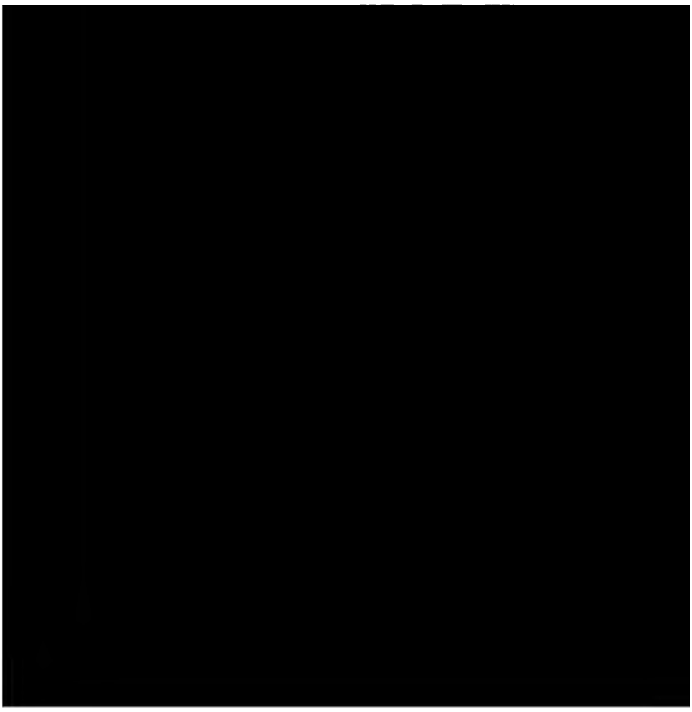


Jernkontoret.

The Iron Trades Office, or "Jernkontor," as it is called, is an institution peculiar to Sweden. It has now been in existence over one hundred and fifty years, having begun its operations as far back as 1748. It was founded by Anders Bachmansson, a Swedish ironmaster, who was subsequently ennobled for the services rendered by him to the iron industry of his country, and assumed the title of Baron Nordencrantz. The primary object of the founder was to render financial assistance to the ironmasters of his country during times of crises. Such histories as that of the Kopparberg Company show the wealth and power of some of the Swedish mining organisations during the sixteenth and seventeenth centuries, but these prosperous years were followed by evil times, and not until well in the eighteenth century did Sweden recover from the impoverishment into which the spirited foreign policy of Charles XII. had thrown her. The iron trade was particularly depressed, and we are told that some time before the foundation of the Jernkontor numbers of ironmasters were financially in the power of their customers, who used this advantage to depress the price of Swedish iron.

When the Office was founded the Swedish Government granted it a loan in order to enable it to begin its career. In addition to that, some thirty thousand Swedish crowns annually were raised by fees from the members, whose contributions were fixed according to their annual output of finished goods. The basis of the loan system was that ironmasters should be allowed to mortgage iron in the State Bank, at 4 per cent. interest, and that the Jernkontor should refund this interest to the owner. The Office was also empowered to buy up iron when necessary.

The same principle of raising contributions has continued all through the career of the Office, but the funds at its disposal have constantly increased, and at the beginning of the present year they amounted to between five and six million crowns. The rules of the Office have, of course, been modified repeatedly in order to bring them into harmony with the changed conditions of trade, but they are still based upon the original scheme of the founder. The rules now in force were sanctioned by King Oscar on January 26, 1894. They declare the principal object of the institution to be the encouragement of the Swedish iron industry, partly by means of loans to the proprietors of works, and partly by means of subventions for scientific and technical purposes. It is satis-



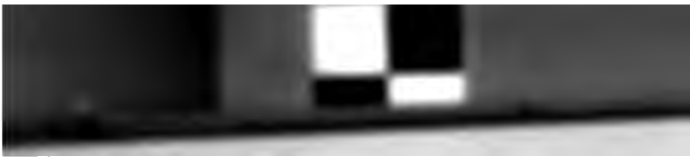
School of Mines at Stockholm. The Jernkontor publishes a periodical of its own, entitled *Jernkontorets Annaler*, which is devoted to scientific and technical matters connected with the iron industry. This journal is one of the oldest of its kind in existence, having been started as early as 1817.

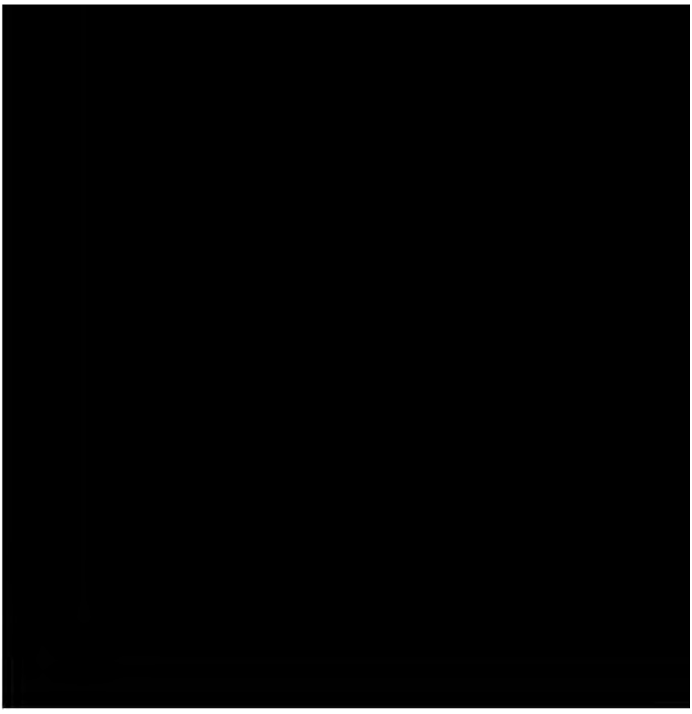
The gold medal of the Jernkontor is a coveted distinction. It is awarded only to those who have been singularly successful in promoting the iron industry of the country. In 1894 the medal was awarded to Mr. R. Åkerman, in 1897 to Messrs. Chr. Aspelin and F. Richter (secretary of the Office), and in this year to Professor G. Nordenström.

The building now occupied and owned by the Jernkontor is situated in the principal square of Stockholm. It was begun in 1873 and completed in 1875, and one of the most striking features of the exterior of the building is the frieze representing the development of iron manufacture, interspersed with a number of medallion portraits of Swedish metallurgists.

The Riddarhus.

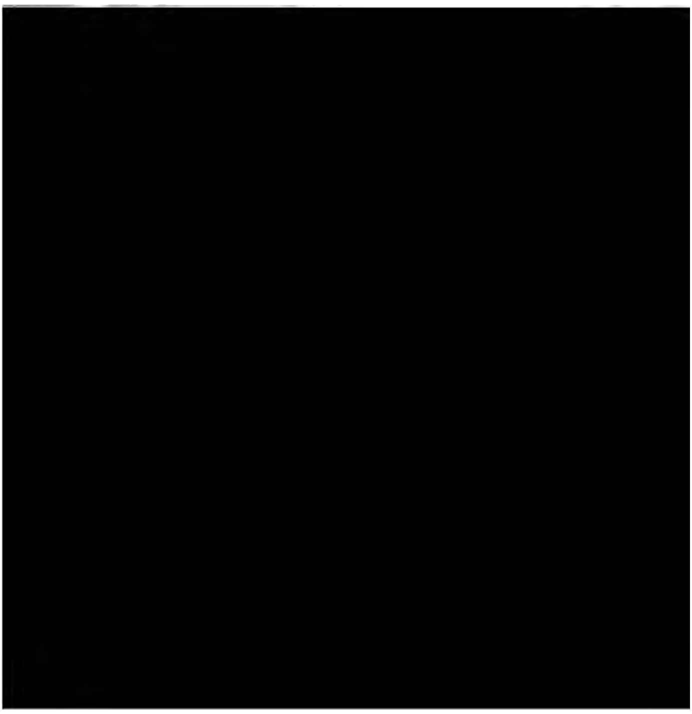
"Riddarhuset," the House of the Nobles, which was kindly placed at the disposal of the Iron and Steel Institute as a meeting-place, is an imposing edifice in the centre of Stockholm. It is one of the oldest buildings in the essentially modern capital, inasmuch as it dates from the middle of the seventeenth century. It was designed by Simon de la Valée, a famous French architect who settled in Sweden, and is in late renaissance style, highly ornamented. The building is practically a national repository of the history and traditions of the Swedish nobility. In the olden days, when the Swedish Parliament consisted of four "estates," the highest of these—the Peers—held their Sessions at the Riddarhus. This continued down to the year 1866, when the modern bicameral legislative system was introduced into the country. The principal feature of the building is the great hall, where the Institute meetings were held. Its ceiling is decorated with a fine allegorical canvas, measuring 48 by 26 feet, by Ehrenstrahl. Another interesting historical relic in the hall is the Speaker's ivory chair, inlaid with representations of Biblical scenes in ebony. This chair dates from 1527, when it was presented to King Gustavus Vasa. But the feature which attracted most attention on the part of the visitors was the collection of the nobles' escutcheons, with arms and motto emblazoned on copper, which almost wholly cover the walls. There are 2892 of these escutcheons, dating from the early sixteenth century to the sixth decade





OBITUARY.

Sir WILLIAM ANDERSON died at his official residence, Woolwich Arsenal, on December 11, 1898. He was the son of Mr. John Anderson, merchant, of St. Petersburg, and was born in St. Petersburg in 1835. He was educated at the High Commercial School there, where he was head of the school and silver medallist, and had conferred on him the Freedom of St. Petersburg. In 1849 he matriculated at King's College, London, and there took many prizes; leaving after the three years' course in applied sciences to become a pupil of the late Sir William Fairbairn in Manchester. From 1855 to 1864 he was in partnership with Messrs. Courtney, Stephens & Co. of Dublin, being engaged chiefly in the construction of various kinds of fittings for railways. He paid much attention to the theory of diagonally braced girders, and contributed papers to the Institution of Civil Engineers of Ireland, of which body he became president in 1863. In 1864 he returned to London to join the old firm of Easton and Amos, whose Erith Ironworks were built under his direction. Eventually he became head of the firm, the name of which was altered to Easton & Anderson. His knowledge of Russian enabled him to translate the works of Chernoff on steel, and the researches of General Kalakoutsky on the internal stresses in cast iron and steel. He delivered courses of lectures on hydraulics to the Chatham School of Military Engineering, on the conversion of heat into work to the Society of Arts, and on the generation of steam to the Institution of Civil Engineers. He was a Fellow of the Royal Society, vice-president of the Institution of Civil Engineers, a past president of the Institution of Mechanical Engineers, a vice-president of the Society of Arts, and a member of the Institution of Naval Architects. At the Newcastle meeting of the British Association he was president of the mechanical section, and had the honorary degree of Doctor of Civil Law conferred upon him by the University of Durham. In 1889 he was appointed by Mr. Stanhope, then Secretary of State for War, Director-General of the Royal Ordnance Factories, and in 1897 he was



Having become wealthy, he retired from active business life about twenty-five years ago. He was an authority on the scientific treatment of iron and steel, and made frequent contributions to scientific publications. He also appeared before Congressional Committees when tariff matters were under discussion. He devoted a large part of his latter years to the study of political economy. In 1896 he published a book entitled "Human Progress" that was the product of many years of study and observation. He was an original member of the Iron and Steel Institute.

ARTHUR MARSHALL CHAMBERS died very suddenly on August 29, 1898, at the age of fifty-five. He was managing director of the firm of Newton, Chambers & Co., proprietors of the Thorncliffe Collieries and Ironworks, and was President of the Institution of Mining Engineers and of the Federated Coalowners of Great Britain. He was one of the best known men in the coal and iron trades of the kingdom. The principal occasion upon which his name came before the general public was during the great Midland coal strike of 1890. In the district where Messrs. Newton, Chambers & Co.'s works are situate he was very popular. Notwithstanding the many calls upon his time, he interested himself in the affairs of Chapeltown and neighbourhood, and on the school boards and local councils did all he could to advance the welfare of his workpeople. He was a justice of the peace, was President of the Sheffield Chamber of Commerce in 1891, and in 1896 was elected Chairman of the Sheffield and Hallamshire Bank. He was elected a member of the Iron and Steel Institute in 1876.

ROBERT PAGE DORMAN died in October 1898, at Middlesbrough, at the age of forty-two. Some years ago he acquired the Ayrton Rolling-Mills, Middlesbrough, and converted them into galvanising and corrugating works. As the head of the firm of R. P. Dorman & Co. he built up a very successful trade in the products of these works, which are at present the only works in the Cleveland district where galvanised and corrugated sheets are made. The output is about 200 tons of sheets a week, most of which are sent to India, Australia, and China. He was elected a member of the Iron and Steel Institute in 1894.

CHARLES CHORLTON DUNKERLEY died at his residence, Hurst Dale, Dunham Massey, on July 22, 1898. One of the most pro-

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for Messrs. Hopkins, Gilkes & Co., at the Tees-side Ironworks, Middlesbrough, and in 1864 erected for them an entirely new blast-furnace plant, since named the Linthorpe Ironworks, at which were adopted a number of new arrangements proposed and designed by Mr. Gjers, among them the patent pneumatic lift or hoist, which has since been adopted at many furnaces in Cleveland, and also in other parts of the country. In 1866 he planned the new furnaces at the Tees-side Works. In 1868 he was engaged in the erection of two blast-furnaces for the West Yorkshire Iron Company, at Ardsley Junction, near Leeds; he also remodelled the Wingerworth furnaces and the Clay Cross Ironworks in Derbyshire, and he afterwards planned the Frodingham Ironworks in Lincolnshire. In 1870 he founded the firm of Gjers, Mills & Co., and put up the Ayresome Ironworks, of which he remained chief proprietor for the rest of his life.

He did not confine his attention to devising improvements in blast-furnace practice and plant alone, for in 1862, when the iron manufacturers of the North of England were considering the question of obtaining a better fettling for their puddling furnaces, he suggested the utilisation of rich magnetic ore, and proved that by the use of such ore a great improvement could be effected in the quality of the iron, besides bringing out a greater weight of puddled bar than the weight of pig iron put into the furnace, through the reduction of part of the fettling. In 1868 he patented a new process for the manufacture of steel rails from the iron of the Cleveland district; but in practice, though the process was successful, the cost was too great. His most important invention, however, was what are known as "soaking pits," into which the steel ingots are dropped from the moulds, and kept at a uniform temperature until they are rolled. The value of the work done by Mr. Gjers during his long and honourable career was acknowledged by the Iron and Steel Institute by the award in 1894 of the Bessemer Gold Medal. He was one of the original members of the Institute, and contributed to its *Proceedings* in 1871 a paper descriptive of the Ayresome Works, with remarks upon the gradual increase in size of the Cleveland blast-furnaces, and in 1882 one on the successful rolling of steel ingots with their own initial heat by means of the soaking pit process.

PHILIPPE ALEXANDRE GOTTSCHALK died in Paris on February 21, 1898, at the age of sixty-four. Born in St. Petersburg on August 13, 1834, he went to Paris in 1843, and became a student from 1850 to

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Arthur Pease died at Callington, Cornwall, on August 27, 1898, at the age of sixty-one. He was the fourth son of the late Joseph Pease, and was born at Darlington in 1837. He occupied a prominent position in the commercial life of his native town, being director of and one of the principal partners in the firm of Pease & Partners, a director of the Middlesbrough Owners Estate, a director of Henry Pease & Co., and owner of the Normanby Ironworks. He also occupied seats on the directorate of a number of other companies, and was chairman of the South Durham and North Yorkshire Building Society. He was a Justice of the Peace and Deputy-Lieutenant for both the county of Durham and the North Riding of Yorkshire, and was an Alderman and Vice-Chairman of the Durham County Council. In 1895, when the Royal Agricultural Show visited Darlington, he offered his park of Hummersknott for the show-ground, and the offer was accepted. He made his entry into Parliament in 1880, when he was returned for Whitby, which town he represented till 1885. In 1895 he was elected member for Darlington. He was elected a member of the Iron and Steel Institute in 1884.

Fritz Salomon died at Constance on October 26, 1898, after a short illness. Born at Brunswick in 1849, he was trained as a pharmaceutical chemist, having studied natural science at the University of Leipzig, where he graduated as Doctor of Philosophy. He subsequently became well known for the chemical memoirs published by him when acting as assistant at Leipzig and at Basel. In 1870 he left Switzerland and was appointed lecturer at his native town of Brunswick, where he became acquainted with Mr. F. A. Krupp, who in 1883 appointed him chemist at his cast steel works. He was elected a member of the Iron and Steel Institute in 1893, and took an active part in the Stockholm meeting in August last.

James Shenton, head of the firm of Shenton & Co., Limited, boilermakers, Hyde, Lancashire, died suddenly on June 25, 1898, at the age of fifty-seven. He was a well-known member of the Manchester District Engineers' Association, leader of the Conservative party in the Town Council, and President of the Newton Moor Conservative Club. He was elected a member of the Iron and Steel Institute in 1891.

Sir Thomas Storey died at Lancaster on December 13, 1898, in his seventy-fourth year. He was seized with paralysis in the spring

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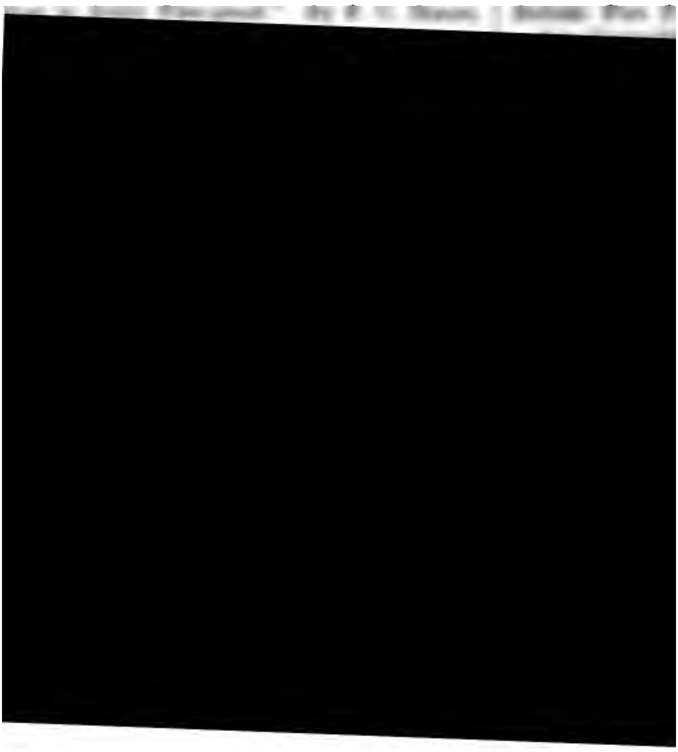
James Williams died at his residence, Bryn-glâs, Newport, Monmouthshire, on May 8, 1898, in his fifty-second year. He was partner in the firm of Watts, Williams & Co., steamship owners and coal exporters, of Cardiff, Newport, and London; a director of the United National Collieries, Limited (Abercarn, Risca, and National). He had a seat on the owners' side of the Sliding Scale Joint Committee, formed in 1875 for the purpose of regulating the wages of the workmen employed in the collieries of South Wales and Monmouthshire. In 1897 he was Chairman of the Monmouthshire and South Wales Coalowners' Association, and Chairman of the Newport Harbour Trust. He was also Chairman of the Committee to draft the scheme for the limitation of the output of coal in South Wales and Monmouthshire. For thirty years he was connected with the Volunteer movement, and at the time of his death he was Lieut.-Colonel in the 1st Monmouthshire Volunteer Artillery. He was elected a member of the Iron and Steel Institute in 1889.

Stephen Wrightson died suddenly on December 2, 1898. He was Secretary of the Carnforth Hematite Iron Company, an undertaking with which he had been connected for over thirty years. He was elected a member of the Iron and Steel Institute in 1887.



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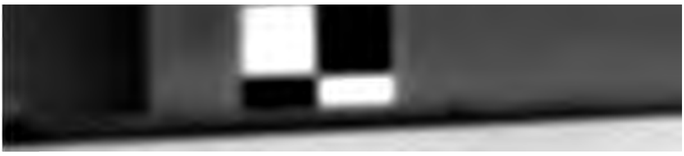

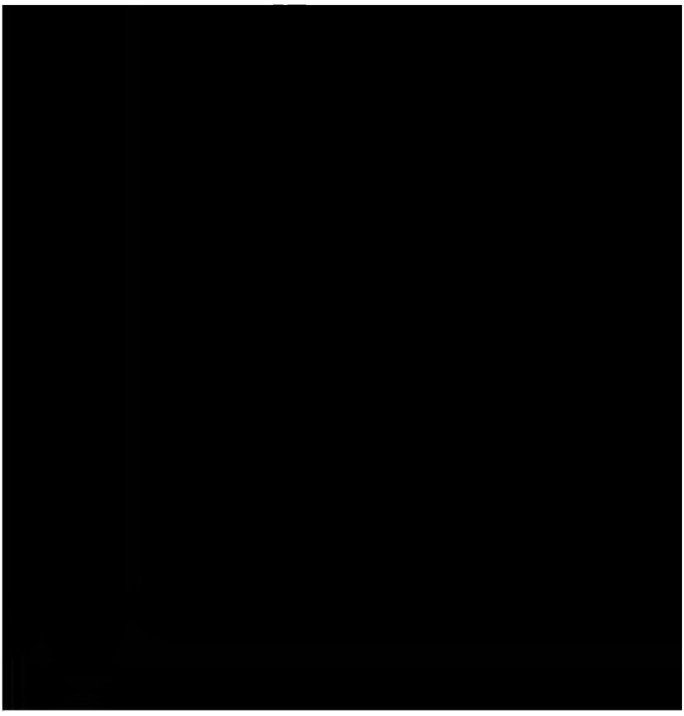

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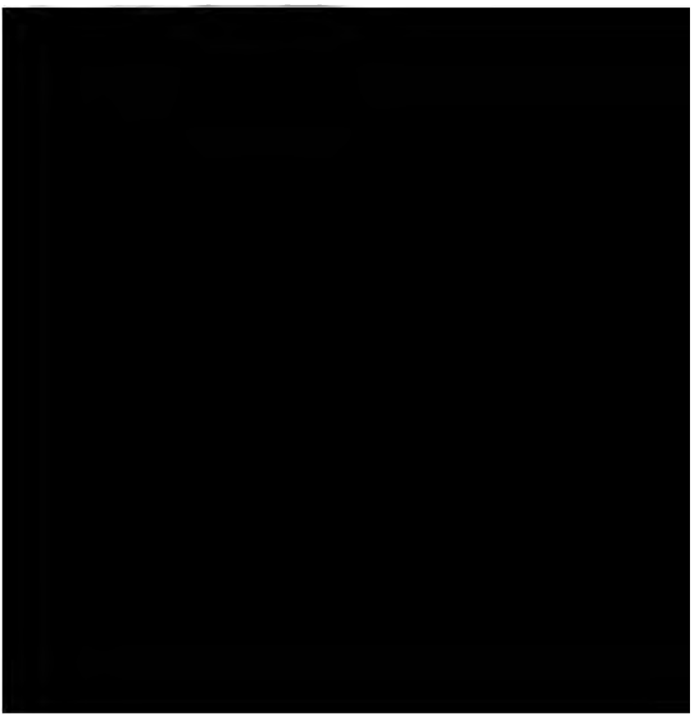
The Publications of the Institute are exchanged for those of the following Institutions :—

LONDON.

Board of Trade.
Chemical Society.
City and Guilds Institute.
Geological Society.
H.M. Patent Office.
Imperial Institute.
Institution of Civil Engineers.
Institution of Electrical Engineers.



United States.

American Association for the Advancement of Science.
American Institute of Mining Engineers.
American Iron and Steel Association.
American Society of Civil Engineers.
American Society of Mechanical Engineers.
Bureau of Statistics.
Engineers' Society of Western Pennsylvania.
Franklin Institute.
Ordnance Office, War Department.
School of Mines, Columbia College, New York.
Smithsonian Institute.
United States Geological Survey.

Austria.

K.k. geologisches Reichsanstalt.
Oesterr. Ingenieur und Architekten-Verein.

Belgium.

Ministère de l'Interieur.

France.

Comité des Forges.
"Revue Maritime." Ministère de la Marine.
Société d'Encouragement pour l'Industrie Nationale.
Société de l'Industrie Minérale.
Société des Anciens Élèves des Écoles Nationales d'Arts et Métiers.
Société des Ingénieurs Civils.
Société Scientifique Industrielle de Marseille.

Denmark.

Tekniske Foreningen.

Germany.

Königliche Bergakademie in Freiberg.
Königliche Technische Versuchsanstalt.
Verein Deutscher Eisenhüttenleute. (Journal "Stahl und Eisen.")
Verein Deutscher Ingenieure.

Italy.

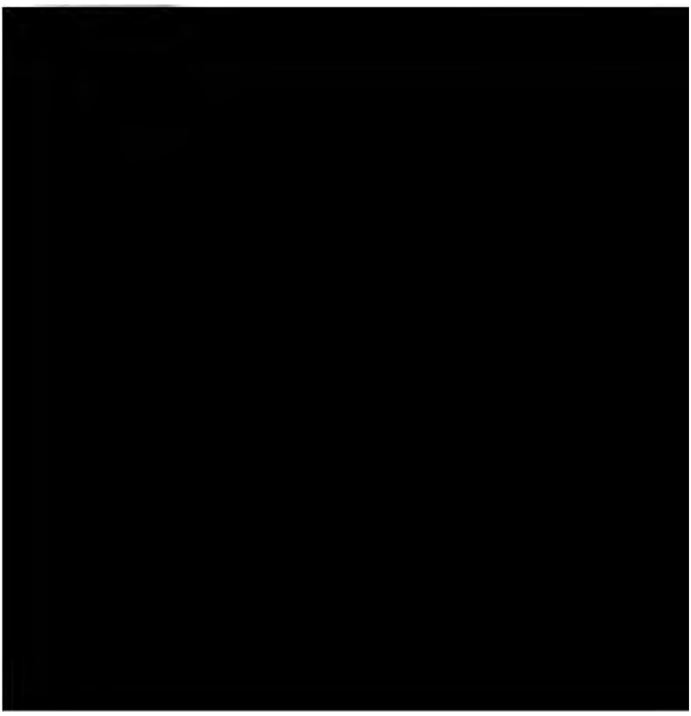
Reale Accademia dei Lincei.

Japan.

Department of Mines.

Sweden.

Jernkontoret.



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"Engineering Magazine."
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"Revue Universelle des Mines."

France.

"Annales des Mines."
"L'Echo des Mines."
"Le Génie Civil."
"Portefeuille Économique."

Germany.

"Annalen für Gewerbe und Bauwesen."
"Chemiker Zeitung."
"Glückauf."
"Verein Deutscher Eisen und Stahl Industrieller."
"Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate."
"Zeitschrift für praktische Geologie."
"Zeitschrift für Werkzeugmaschinen und Werkzeuge."

Italy.

"L'Industria."
"Rassegna Mineraria."

Spain.

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Sweden.

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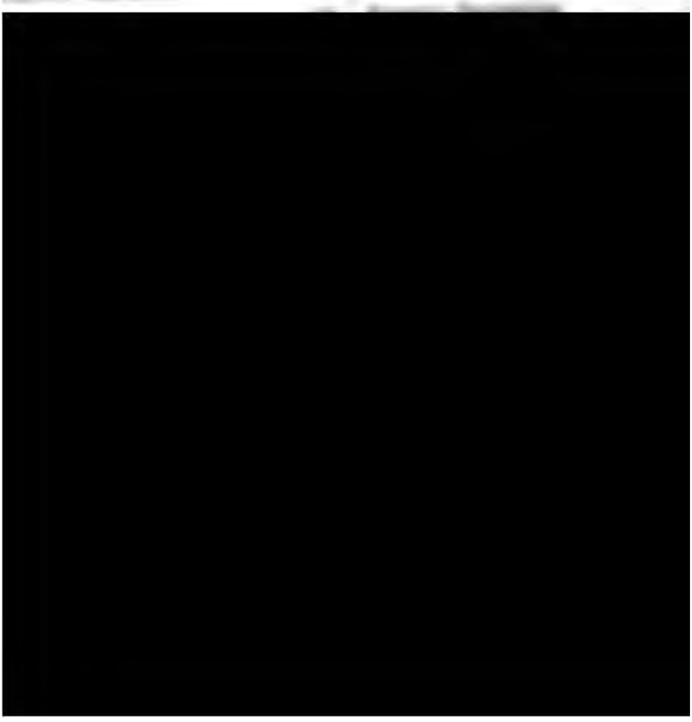


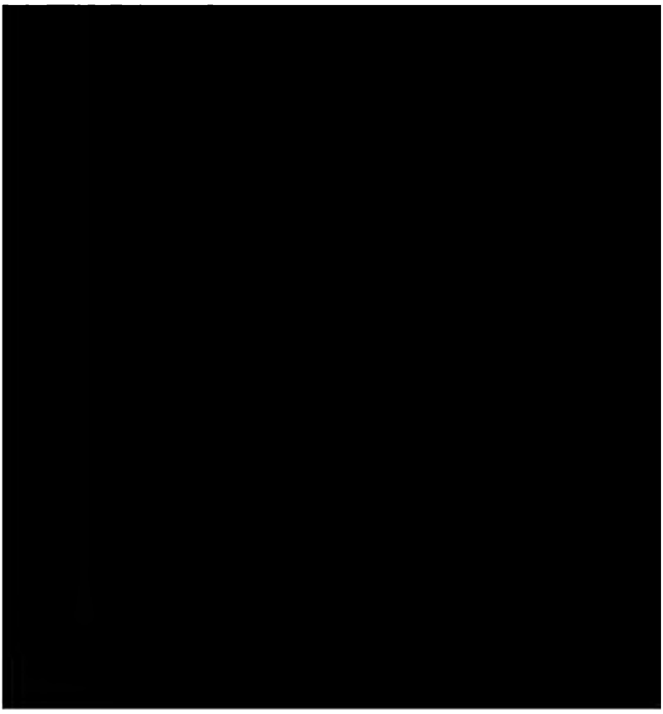
IRON ORES.

CONTENTS.

I.—*OCCURRENCE AND COMPOSITION.*

The Hodbarrow Hæmatite Mines.—The Hodbarrow hæmatite* mines have for many years been the most productive in Cumberland and Lancashire, and until the discovery of Lake Superior deposits, turned out a greater tonnage of iron ore than any other iron ore mine in the world. The nature of the deposit is to some extent similar to the other hæmatite mines of the western division of the county round Cleator, Frizington, and Egremont, and the ore is of similar character, but richer in iron. The Hodbarrow ore deposits are found immediately along the sea foreshore, and not far from the estuary of the tidal river Duddon. The full extent of the deposits is not known, as they extend so far seaward and are so scantily covered that any considerable working further under the sea might result in the loss of the deposits and of the mines now being worked. The length of the chief deposit is a little over 1000 yards, and its breadth some 400 odd yards. Along the north and south foreshore, where great bodies of ore are only overlain by a thin covering of clay, gravel, and drift, a sea wall was erected about eleven years ago, and it is now found necessary to build another similar wall further seawards, on account of the recent great inrush of the tide. At various times there have been in-breaks of the sea, particularly at spring tides, and thousands of tons of sand have been rushed into the workings. The last break has, however, been the most serious, as it was found that a large

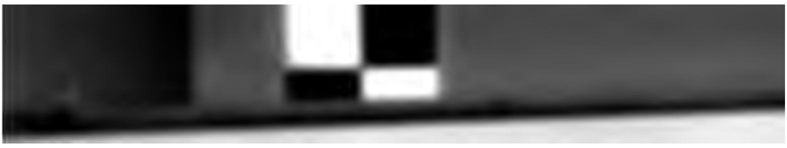
* *Colliery Guardian*, vol. lxxv. p. 991.



charcoal blast-furnaces which have now been abandoned. The cause of this is the ravages made on the forest and the construction of railways, which enable the wood to be exported, the price of timber having increased to such a degree that it is no longer profitable to convert the wood into charcoal for iron-smelting. All these works in the mountains possessed their own iron mines, and these, too, have now been abandoned. Two such mines are the magnetite mines, Tobias and Melchior, at Niedergrund, near Zuckmantel, which formerly belonged to the Buchbergsthal ironworks, and yielded ore of excellent quality. Since 1864, however, they have lain idle. The magnetite occurs as beds in a dark green chlorite schist of Lower Devonian age. Two beds of ore are known. The Tobias bed is 3 to 10 feet thick, with a dip of 40° to 50° south-west. The ore is partly massive magnetite and partly magnetite banded with poorer ore of a greyish green colour. The ore yields 30 to 50 per cent. of iron, and by hand picking ore averaging 40 to 45 per cent. of iron can be obtained. The mine comprises an adit level 100 yards in length, and a shaft. The ores were formerly obtained by underhand stoping. The depth from the surface to the adit is about 20 yards. The Melchior Mine also comprises a shaft and an adit level; but as the upper portions had been exhausted a deeper level was begun. The bed forms a lenticular mass 10 to 15 yards in thickness, extending for 100 yards. The ore contains 40 to 50 per cent. of iron, and yields on hand picking an average of 45 to 50 per cent. of iron. The depth to the adit is 25 yards. The incompleted deep level is 70 to 80 yards deep. At the present time the adit and workings of the Tobias Mine are accessible, and the ore may be investigated. The shaft has fallen in. At the Melchoir Mine the shaft, the workings, and the deep level are accessible, but the adit level has fallen in. The mines still contain an abundance of ore, and might be worked for many years on a large scale. It would be necessary to drive an adit at a depth of 200 yards, and to erect a wire ropeway to Niedergrund. From the mines to the railway station at Zuckmantel it is half-an-hour's walk.

Iron Ore in France.—G. Rolland,* who is engaged on the geological survey of France, has prepared an underground topographical map of the ferruginous formation of the new Briey basin. In referring to the matter he observed that an event of the first importance for the future of French metallurgy was the unexpected discovery of the

* *Comptes Rendus de l'Académie des Sciences*, January 17, 1898.



German territory is concerned, but are not inconsiderable on French territory. Apart from these the ore beds are confined to the plateau of Briey, and especially to the eastern portion. This plateau lies between the Moselle and the Maas, and has an average height of about a thousand feet above sea level. By two side valleys this plateau is really divided into three.

Dealing in particular with the district to the north of the Fentsch, the author first describes the topography of the district, and then considers the question of the geological structure of the country. The bean ore of the forest of Aumetz is chiefly brown hæmatite, and the following is an analysis :—

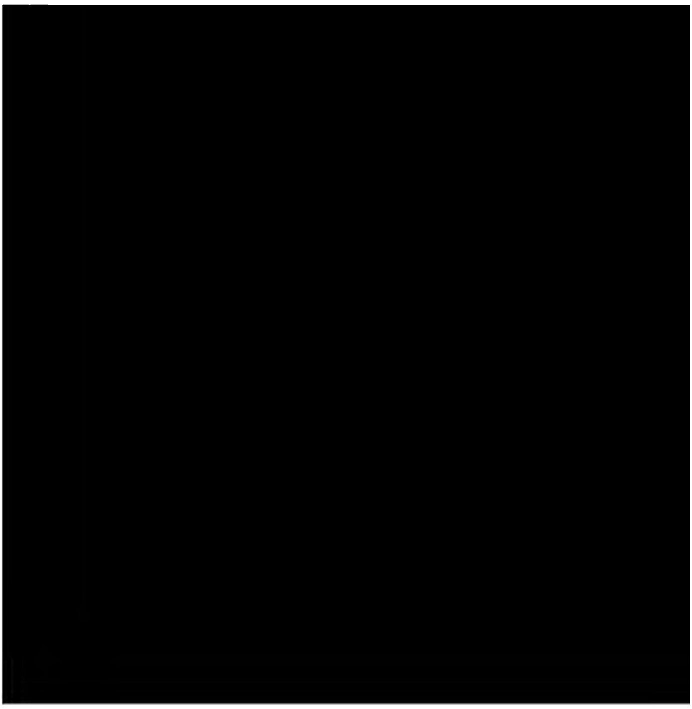
Fe_2O_3.	Mn_2O_3.	H_2O.	Al_2O_3.	MgO.	SiO_2.
68·5	0·5	11·0	2·5	0·4	16·5

On account of their low contents in phosphorus, these bean ores were considered in former times as valuable ores of iron, and were won on a considerable scale. The author next passes to a petrographic consideration of the minette formation. The composition of the workable beds varies between the following limits :—

	Per Cent.
Iron	30 to 40
Silica	4 to 20
Lime	4 to 20
Alumina	2 to 8
Phosphorus pentoxide	0·5 to 2·0

In addition there is up to 0·5 per cent. of MgO and Mn_2O_3. Sulphur occurs only in traces. The form in which the phosphorus pentoxide occurs is doubtful. French authors consider it to be in combination with lime, whilst German authorities hold it to be combined with iron. The percentages of silica, lime, and clay are often much higher than mentioned above; silica sometimes is as high as 40, while in other beds the percentages of lime and marl make up 50 per cent. of the total, the beds ceasing to be of any value as ore. The lines of demarcation between the beds and partings are often far from definite. These partings consist of sandstone, marl, limestone, and all kinds of intermediary products.

Dealing next with the various ore beds, the author gives a detailed list of the seams of ore that have been met with, and other information concerning them. They are numerous, but vary considerably in thickness and value as ore. Thus the *black* bed, the lowest of all, has



The limestone nodules which the seam carries make up from one-third to two-fifths of its total thickness. From Esch both eastwards and southwards the seam diminishes in thickness, and the limestone nodules increase in quantity. Two similar beds are met with near this one. Above this group comes a marly bed of very variable thickness, and above this the "red-sandy" bed. This latter is found to contain *Ammonites Murchisonæ*, *Pholadomya reticulata*, and *Lithodendum Zollerianum*. In the German district this bed attains a greater thickness than any of the others, reaching in places 50 feet. It is marked by its contents of sandy granules. At the Dettingen Mine, where this ore is mined, it contains—

Iron.	Lime.	Silica.
36	2 to 3	26 to 27

The author next proceeds to a consideration of the ore reserves, and calculates these to amount altogether in German Lorraine to 1930 millions of tons. Other points connected with the seams and the faults that occur are discussed, and a bibliography is also given.

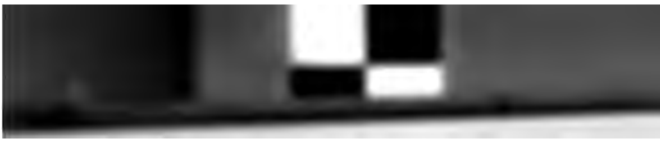
The Bentheim-Ochtrup Clay Ironstone Deposits.—B. Kosmann * deals further † with the deposit of clay ironstone of the Bentheim-Ochtrup basin. A further investigation of this basin has now been made under the author's supervision, and at five selected points. These proved that the ironstone beds show regular bedding and deposition, beds of clay, marl, and ironstone following regularly one upon the other. The author considers that about 500 such ironstone beds must exist in the basin.

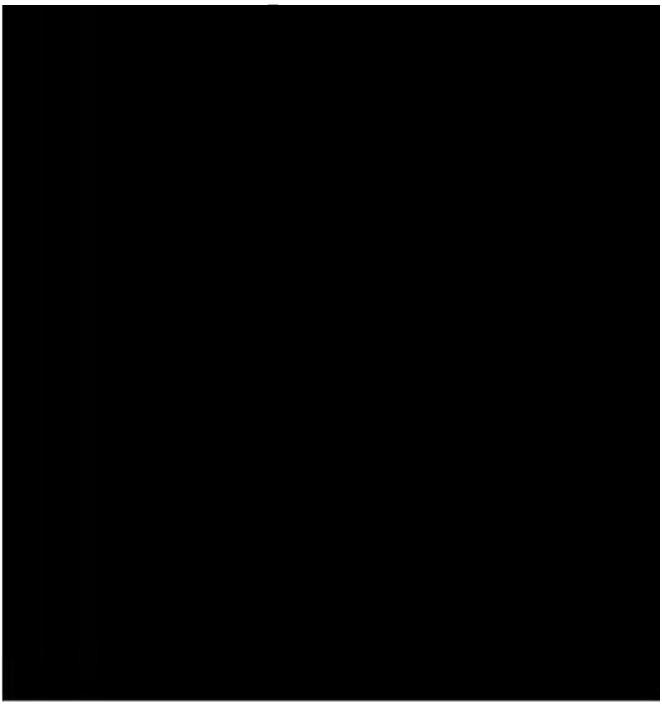
These deposits are also described by H. Kette.‡

Iron Ores of the Siebengebirge.—E. Kaiser § has published a complete geological survey of the northern flank of the Siebengebirge, in Rhenish Prussia. Clay ironstone is of frequent occurrence. The bands vary in thickness from 7 to 20 inches, and the ore also occurs in the form of nodules. The greater portion of the memoir is occupied by a description of the lignite deposits of the district.

The Stahlberg Iron Ore Deposits.—According to Hans Mentzel, ‖

* *Stahl und Eisen*, vol. xviii. pp. 623–625.
† *Journal of the Iron and Steel Institute*, 1898, No. I. p. 340.
‡ *Glückauf*, vol. xxxiv. p. 436.
§ *Verhandlungen des naturhistorischen Vereins der preussischen Rheinlande*, vol. liv. pp. 78–204.
‖ *Zeitschrift für praktische Geologie*, 1898, pp. 273–278.





workings were in existence, however. At the end of the past century the quantity of ore mined annually at Rio Marina was only about 100 tons, whereas now the quantity reaches 200,000 tons, and could be considerably increased were this not the maximum output allowed under the concession by the Italian Government. No smelting operations are in progress on the island. The chief portion of the ore is exported to England. Open-cast workings are still chiefly employed, the ore occurring in pockets in clay slates and not occurring in veins. The ore is freed from gangue by washing, sea-water being used for this purpose. The miners distinguish two kinds of ore, one of which they call "ferrata," and the other "lucciola." The first has almost the colour and lustre of polished steel, and is heavy and hard. The texture of the second is much looser, consisting of scales, which reflect light strongly. The surface of the mountain right down to the water's edge is covered by a reddish earth, in which such micaceous iron ore occurs in large quantity. Iron ochre also occurs, and in very many different colours. The beautiful rainbow colorations which are so often observable on the crystals are due to the presence of a slight film of ferric oxide.

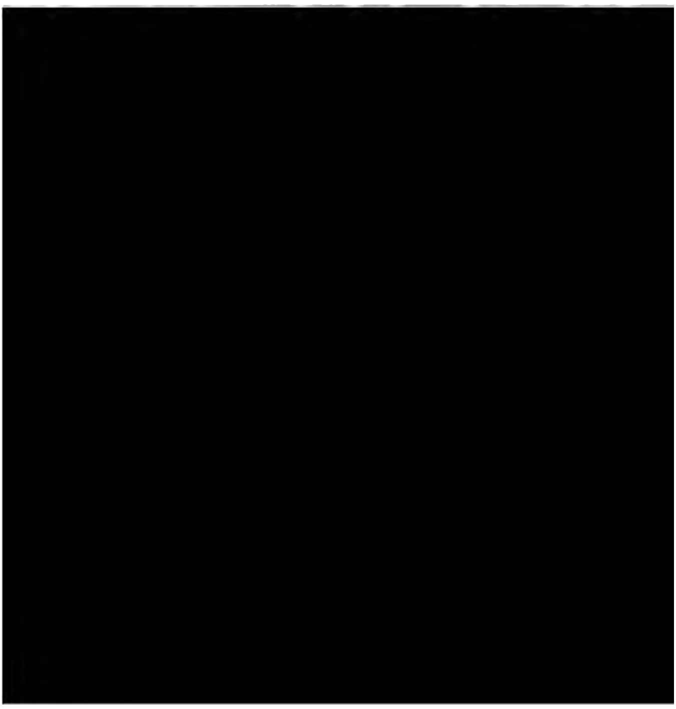
The iron ore deposits of Elba are described by A. H. d'Escailles* and by P. Toso.† The latter gives the following representative analyses:—

	Iron.	Phosphorus.
	Per Cent.	Per Cent.
Rio ore, washed	60·00	0·016
Rio ore, unwashed	54·55	0·024
Vigneria ore	61·05	0·012
Terranera ore	68·15	0·005
Calamita ore	58·61	0·015

The Elba iron ore mines, which were leased in June 1897 to an English-Belgian syndicate under certain restrictions,‡ are estimated to contain 7,990,000 tons of ore in the six mines. All the deposits are worked open cast. §

Iron Ore in Norway.—H. T. Newbigin || describes the siliceous

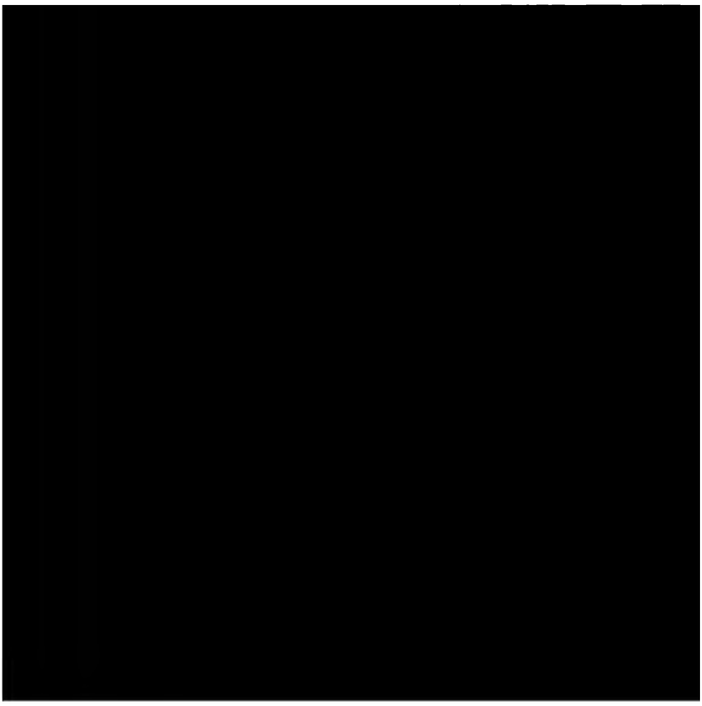
* *Mining Journal*, vol. lxviii. pp. 1090, 1112.
† *Bollettino del Reale Comitato Geologico d'Italia*, vol. viii. pp. 216–248.
‡ *Journal of the Iron and Steel Institute*, 1897, No. I. p. 601.
§ *Iron Age*, May 26, 1898, p. 10.
|| *Transactions of the Institution of Mining Engineers*, vol. xv. pp. 154–171, with map.



other slates, the ferruginous quartz schists forming the main portion of the upper half of this lower series. These latter vary extremely in colour, according to their varying percentage of iron. They consist solely of iron ore and quartz, the latter being in the form of small and more or less round and perfectly transparent granules. Some beds consist solely of such quartz granules, while in others these are coated or partly replaced by iron ore. If the mass contains less than 40 or 45 per cent. of iron it is not considered rich enough to mine, and the material is not named "ore" till it exceeds this percentage. The poorer ores, averaging about 45 per cent. of iron, are smelted on the spot; only richer ores, with some 60 per cent. of iron, are exported. The following are partial analyses :—

Iron, per cent.	62·72	65·42	66·60	67·43	69·6
Silica, "	7·58	2·46	1·71	0·78	0·91

It will be seen from these how the percentage of silica diminishes as that of the iron increases. Ferric oxide is the oxide most commonly present, though magnetite is also found. The typical form of the iron ore bodies is a lense elongated horizontally, and tapering off to a wedge in depth. These lense-shaped bodies vary greatly in size, the longest being perhaps rather less than two miles in length. The depth to which these ore bodies are capable of being mined reaches to about 76 yards, and their breadth to about 175 yards. The beds themselves do not form compact ore masses, but show bedding and folding, and in all respects resemble ferruginous quartz schists. They occupy no definite stratigraphical position of their own, simply forming local enrichments of the beds, in which iron ore replaces the quartz granules. The statement of Trasenster, that the iron ores occur in two horizons, requires further proof. The ore consists chiefly of red hæmatite, in part pseudomorphous after magnetite. On the average about 8 per cent. of the ore mass consists of magnetite. The quantity of phosphorus present varies from 0·013 to 0·02 per cent., averaging about 0·017. The ore is consequently one of the poorest in phosphorus that occurs in Europe. Calcium, magnesium, and manganese are only found in the ore in traces. Some beds of argillaceous red hæmatite also occur in this neighbourhood, not in the ferruginous quartz schists, but in the upper system of clay slates. The various iron ore deposits are described by the author in detail. The total quantity of iron ore raised annually in recent years has been about 100 million poods. In view of the fact that the total remaining ore supplies in the Krivoi Rog district are estimated at not more than 20 million tons, it is evident that at the present rate of



Iron Ore in the Ural.—According to G. Kamensky,* the ore deposits of the Ural may be divided under two heads: (1) Numerous small deposits having the character of pockets or thin seams of ore; and (2) several extremely thick deposits and seams of ore, six being known at present. The deposits of the first group probably will continue to be the source from which most of the existing works draw their supplies. They occur almost everywhere in the district, and are more accessible with the present means of transport than the more massive deposits, although their exploitation cannot be so economical. The poorest deposits are situated in the North Ural. The northern portion of the actual mountain chain contains two deposits belonging to the second category, the Koutimsky and the Ubrishkinsky, which give an ore of high quality, containing 60 to 65 per cent. of iron. Unfortunately, both these localities are so inaccessible that, notwithstanding the abundance of forest, they cannot be worked on a large scale. The Bogoslovsky mining district works deposits yielding ores containing 50 to 60 per cent. of iron. The works of the Central Ural are better able to avail themselves of the two vast Visokogorsky and Goroblagodatsky deposits situated there. This district uses about 400,000 tons of ore yearly, 200,000 tons of which are supplied from the Visokogorsky and 65,000 tons from the Goroblagodatsky deposits, the remainder coming from smaller mines whose ore, although poor, forms a useful addition to the furnace charge. The former deposits give a 60 to 66 per cent. magnetic ore, containing an exceedingly small amount of impurities, and the ore is self-fluxing, so that it can be smelted without the addition of fluxes. These two deposits are so extensive that they could supply ore to the whole of the Urals for many decades. In 1894, Urbanovitch estimated the Blagodat deposit alone to contain 5,050,000 tons of ore. As regards their ore supply, the ironworks of the Central Ural may be divided into two groups, those which possess a considerable surplus, and even supply other works, and those which are obliged to buy ores. Hence, the mining and sale of iron ore as a separate industry apart from its smelting is widely developed in the Central Ural.

The Southern Ural have far greater mineral wealth at their disposal than the north and central districts; the iron industry is mainly centred upon two deposits of the second category—the Bakalsky deposit in the region of Zlatoust, and the Mount Magnitny in the property of the Beloretzk works. The former furnishes the Zlatoust

* *Colliery Guardian*, vol. lxxvi. pp. 28-29.

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in thickness has recently been discovered. It has been proved over an area of about a hundred square miles, and contains 36·2 per cent. of iron in its raw state, or 50·38 per cent. after calcination.*

Manganese Ore in the Caucasus.—According to F. Drake,† manganese ores are known to exist in the Caucasus, in the Government of Kutais, near the village of Chiaturi; in the same Government near the Choruk River, southward from Batum, and in the Governments of Erivan and Tiflis. In smaller quantities they are found in various other places; but all the ore worked at present comes from Chiaturi, the export in 1897 being 201,612 tons, and this year it is expected to reach 300,000 tons.

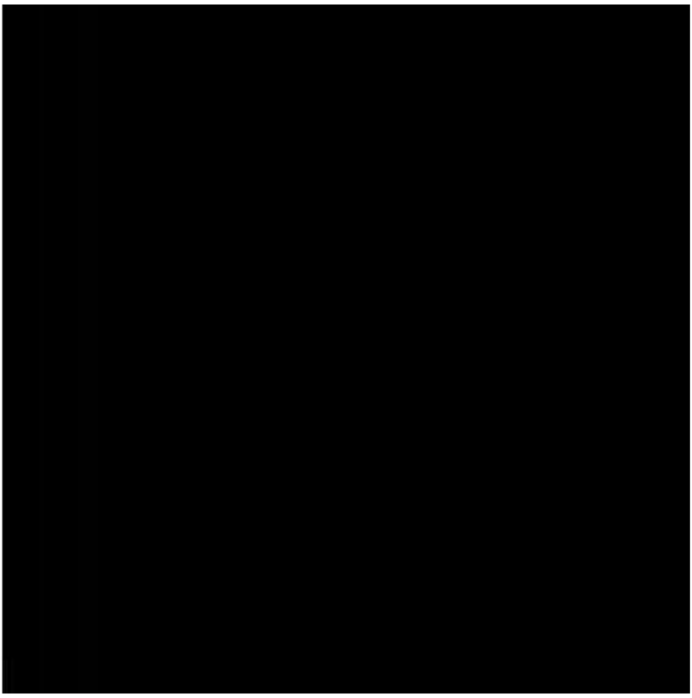
The ore occurs in a bedded deposit in a brown sandstone of Miocene age, and has an average thickness of between 6 and 7 feet. Its dip, which is slight and fairly regular, is south-easterly. Slight faulting of the formation has occurred in some instances; but few folds are observed, and the bed is free from sudden or extreme variations from the average thickness. The deposit has a distinctly stratified structure, and is composed largely of pyrolusite, but other oxides of manganese occur. The ore is soft and rather liable to break up during transport. Over limited areas the unpicked ore contains 50 per cent. of manganese, but by careful sorting it may be raised to 61 per cent. As a rule, the exported ore contains 46 to 56 per cent. Phosphorus averages 0·16 per cent., and silica not over 8 per cent.

The first shipments were made in 1879, and since then the production has steadily increased until this deposit now supplies about one-half of the world's demand. The production last year was 231,868 tons. The ore fields are owned by a very large number of proprietors, mostly natives. The labour market is recruited from the peasantry, the averages wages being 1s. 8d. per day for a man, and 3s. for a man and horse. About 2700 men are employed. The total cost at the mine per ton of clean ore is approximately as follows:—

	s.	d.
Labour for mining, haulage, and cleaning	1	7½
Timber and other supplies	0	2
General expenses	1	4
Royalty	0	8½
Total	3	10

* *Génie Civil*, vol. xxxii. p. 322.

† *Transactions of the American Institute of Mining Engineers*, Atlantic City Meeting (advance proof).



parish of Ludvika is of ancient date, but is now in a depressed condition. The ores are magnetite and red hæmatite, and two important natural sources of power are available, the Ludvika Falls representing 2500 horse-power, and the Lernbo Falls representing 3000 horse-power. The ore field covers 50,000 square metres, or one-sixth of the ore surface of Central Sweden. From 1871 to 1875 the output from twenty-five mines averaged 37,259 tons of iron ore annually, but in 1896 there were only seven mines working, producing an aggregate of 29,776 tons. The ores are (1) calcareous or somewhat quartzose magnetites in the older gneiss; (2) quartzose ores in flinty gneiss; (3) the lower calcareous ores in the same rock; (4) ores in the more recent gneiss; and (5) the upper calcareous ores in flinty gneiss. The ore field is in direct railway communication with Gothenburg, Gefle, and Oxelösund. The 5898 tons of ore raised in 1896 from the Lekomberg mines averaged 55 to 65 per cent. of iron, 0·4 to 1·2 per cent. of phosphorus, and 0·01 to 0·02 per cent. of sulphur.

Iron Ore in the Alps.—A. Bordeaux * publishes an important memoir on the mineral resources of the Alps. He refers in particular to the deposits of spathic iron ore at St. Georges d'Hurtiéres and at Presle.

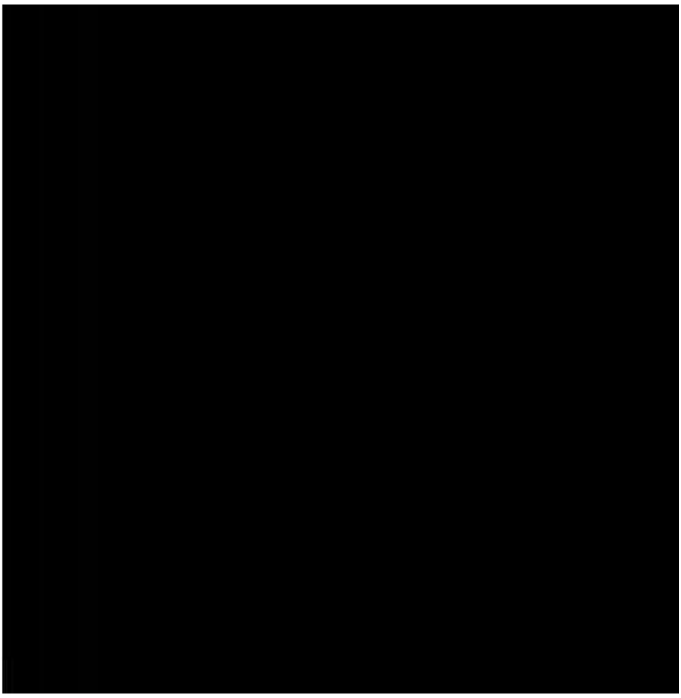
Iron Ore in India.—According to P. N. Bose,† laterite rocks have been met with in small patches in the Phen and the Holon valleys, Mandla district, Central Provinces. Economically they are important as yielding in places iron ore of good quality. Lateritic ore picked up from the bed of a stream near Lalpura in the Phen valley affords an intermittent supply for one primitive furnace. Others are said to exist in the Deccan trap area north-east of it.

The iron ores of the Javadi Hills, Madras, have been examined by C. S. Middlemiss. ‡ The results show that the upper parts of the ridge contain several beds of magnetite, with hæmatite and quartz of the same general arrangement and appearance as those of the Kanjamalai and Tirtamalai. At the western base of the hills the mottled gneiss ascends about one-third of their height. Then comes hornblendic gneiss and a series of magnetic iron beds interbedded with hornblendic, micaceous, garnetiferous, and hypersthene-bearing gneisses. These

* *Revue Universelle des Mines*, vol. xliii. pp. 1–43.

† *General Report on the Work carried on by the Geological Survey of India*, Calcutta, 1898, p. 43.

‡ *Ibid.*, p. 20.



deposits in New Brunswick.* The ore, a soft wet stuff, containing 50 per cent. of water, is 5 to 30 feet in thickness, and covered with a slight layer of earth. It is dried in a revolving cylinder 28 feet long and 5 feet in diameter, and screened. The coarse stuff is disintegrated, and all the material is mixed with some binding material, after which it is pressed into cylindrical briquettes 3 inches in diameter and 2½ inches long, for conversion into ferromanganese at a blast-furnace in Nova Scotia. The ore dried at 212° F. shows:—

Manganese.	Iron.	Sulphur.	Phosphorus.	Silica.
48·24	5·70	0·096	trace	1·88

Lake Superior Iron Ore.—In a review of American practice of iron and steel manufacture, A. P. Head † gives the following table:—

	Vermillion Range. Average of Six Mines.	Gogebic Range. Average of Two Mines.	Menominee Range. Average of Six Mines.	Mesabi Range. Average of Twelve Mines.	Marquette Range. Average of Nine Mines.
Iron	65·01	60·72	56·29	63·22	61·52
Phosphorus	0·08	0·05	0·08	0·044	0·09
Silica	3·89	3·63	11·77	3·77	6·48
Manganese	0·04	2·44	0·23	0·59	0·36
Alumina	1·20	1·49	1·27	1·21	1·99
Lime	0·48	0·17	1·61	0·41	0·71
Magnesia	0·17	0·11	1·82	0·12	0·49
Sulphur	trace	0·01	0·004	trace	0·014
Organic and volatile	2·22	9·00	3·93	10·70	2·30

The ships used for transport of ore on the great lakes are described, and also the ore-handling plant. The Alabama ores are also referred to.

The average analyses either for the last year or those expected for the present year of a large number of the mines in the five great ranges have been published in tabular form. ‡

J. E. Jopling § gives some notes on the discovery, development, and resources of the Marquette range. Sections are given to show the geological relations of the hard and soft ores to the quartzite, soapstone, and jasper. The history of the field is shortly traced, and statistics are given of the abandoned mines and of the mines at work.

* *Engineer*, vol. lxxxvi. p. 32.

† Paper read before the South Staffordshire Institute of Iron and Steel Works Managers, March 1898.

‡ *Iron Trade Review*, vol. xxxi., No. 10, p. 16.

§ *Transactions of the American Institute of Mining Engineers*, Lake Superior Meeting, 1897 (advance proof).

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of iron ore, observing that the ores found are chiefly magnetites and red hæmatites. In several provinces the ore deposits are of considerable importance. Brown and spathic ores are of very rare occurrence, the latter being little more than a rare mineral. The rocks in which the ores occur are chiefly granitic, with crystalline schists and limestone. The ore deposits at present known are estimated to contain seventy million tons of ore, but new deposits are being constantly discovered. Micaceous iron ore from one deposit yielded by dry assay a pig iron containing—

Graphite.	Combined Carbon.	Mn.	Si.	S.	P.
3·07	0·28	trace	1·70	0·051	0·133

The average contents of the ore in iron was 55 per cent. A similar ore from another deposit contained from 44 to 68 per cent. of iron, and from a trace to 0·07 per cent. of phosphorus. It yielded on assay a button containing—

Graphite.	Combined Carbon.	Manganese.	Silicon.	Phosphorus.
2·42	0·25	0·16	3·36	0·13

Red hæmatites from various deposits gave on analysis the following results:—

Fe_2O_3.	FeO.	Al_2O_3.	SiO_2.	CaO.	P_2O_5.	SO_3.
67·94	trace	0·55	31·37	trace	...	...
80·32	1·15	...	...	...	0·34	trace
90·51	trace	2·30	...	0·44	0·69	0·42

As previously observed, the iron ores found are chiefly magnetites, and Japanese iron is chiefly made from them. The following are analyses of such ores from various districts:—

	Fe_2O_3	FeO.	MnO.	S.	P_2O_5	SiO_2
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
1	24·85	69·25	trace	...	0·24	5·62
2	26·09	67·69	trace	...	...	3·95
3	25·74	65·55	...	trace	0·24	3·51
4	28·81	67·02	0·25	1·71	0·47	1·84
5	24·99	69·85	...	trace	0·07	3·13
6	24·71	66·24	trace	trace	trace	4·47
7	24·64	64·41	...	trace	...	8·58

Pig iron made from magnetite ores contains from 0·016 to 0·09 per cent. of sulphur, 0·03 to 0·09 of phosphorus, nil to 0·81 of copper, and

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have been overflowed by a massive, highly ferruginous trap, and the ore bodies are the secondary products of its decomposition, either by the solution and replacement of coralline, where the trap and coralline came into contact, or the alteration of the eruptive rock in places, followed by concentration.

The ore is a Bessemer hæmatite, and appears in several forms, but chiefly the hard amorphous steel-blue variety. An average analysis shows—

	Per Cent.
Iron	63·100
Manganese	0·097
Copper	0·056
Sulphur	0·072
Phosphorus	0·029
Alumina	0·712
Lime	1·060
Magnesia	0·381
Silica	7·225

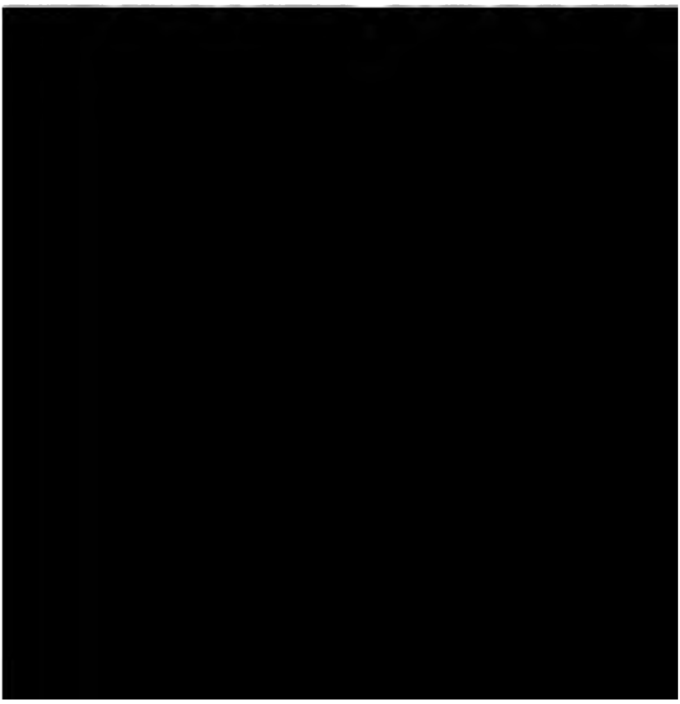
The ore outcrops near the tops of the hills, and is worked opencast. It is run down by self-acting inclines to a solidly-built dock at Daiquiri, where it is loaded from pockets holding 2000 tons directly into the vessels by shoots.*

An interesting account of the mineral resources of Cuba has been published by R. Cabrera.† The deposits of hydrocarbons, asphalt, and mineral oils are extremely abundant and of excellent quality, both for fuel and lighting purposes. Large masses of hæmatite and of magnetite are found. The total exports of iron ore from Santiago from the opening of the mines in 1884 to the end of last year have amounted to 3,488,643 tons. Manganese ore is also extremely abundant in Santiago de Cuba.

Manganese Ore in Colombia.—The Panama manganese mine is, according to the *San Francisco Chronicle*, a valuable deposit of this mineral opened up within the last two years by Baltimore capitalists. It is situated on the Atlantic coast of the United States of Colombia, about 40 miles north of Colon, and is worked by a company with a capital of 200,000 dollars. The ore is easily mined, and is carried by a wire ropeway to the foot of the mountains, whence it is taken by nine miles of railway to the shipping port of Nombre de Dios. Within the last eighteen months the company has shipped 24,000 tons of ore

* *Iron and Coal Trades Review*, vol. lvi. pp. 558–559, with illustrations.

† *Journal of the Franklin Institute*, vol. cxlvi. pp. 26–45.



more common occurrence in the district of the river Maecuru than elsewhere, but do not occur even there in any large quantity.

Iron Ore in the Congo.—X. Stainier * gives a sketch of the geology of the Congo, and briefly notes the mineral deposits of that region. Iron ore is abundant, limonite, specular ore, and magnetite being found. Important deposits of coal have not been found. Native iron manufacture is also described.

Recent Researches on Meteorites.—W. N. Hartley † and Hugh Ramage give the results of a spectrographic analysis of iron meteorites, siderolites, and meteoric stones, and arrive at the following conclusions:—1. The composition of different meteoric irons is very similar, though the proportions of the constituents differ to some extent. 2. Copper, lead, and silver are common constituents of meteoric irons, and occur in variable proportions, as is the case with iron ores of different varieties and different kinds of manufactured irons. 3. Gallium is a constituent in varying proportions of all meteoric irons, but not of all meteorites. It occurs in one of the siderolites examined. 4. Sodium, potassium, and ribidium are constituents of meteoric irons, but only in minute proportions. 5. Chromium and manganese are found in meteoric stones, but not in the irons, though very minute traces of manganese have been detected in two specimens. 6. Nickel is found as a principal constituent in all meteorites, meteoric irons, and siderolites. Cobalt occurs in the two latter varieties only. The chief points of difference between telluric and meteoric iron is the absence of nickel and cobalt in any considerable proportion from the former, and the presence of manganese; while meteoric irons contain nickel and cobalt as notable constituents, and, except in minute traces, manganese is absent.

H. A. Miers ‡ deals historically with the changes in the way that people generally, and scientific men especially, have regarded the evidence for the ex-terrestrial origin of meteorites. Many contemporary accounts of meteoric falls from the earliest up to the present times are quoted. At an early period it was certainly considered that certain stones had fallen from the sky, but the accounts are often uncertain, and the consideration of the matter complicated, partly on account of

* *Guide de la Section de l'Etat Indépendant du Congo à l'Exposition Bruxelles-Tervueren*, 1897, p. 269; *Transactions of the Institution of Mining Engineers*, vol. xv. pp. 491–501.

† *Scientific Proceedings of the Royal Dublin Society*, vol. viii. pp. 703–710.

‡ Lecture delivered in Magdalen College, Oxford, February 19, 1898; *Science Progress*, vol. vii. pp. 349–370.

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their fall, as would be expected if they had fallen on to the rocky earth in which they were found, and this must be explained by the supposition that they fell on to the great ice cap or into an enormous snowdrift. The iron in the three masses is of unequal hardness, due in all probability to their different sizes and rates of cooling; but the "woman" is the softest, and has been extensively worked by the Eskimo to obtain scraps of iron for tool-making. When *in situ* it was surrounded by a huge pile of broken trap boulders, which had been used as hammers. Terrestrial origin for these masses is clearly disproved.

According to Oliver C. Farrington,* from the weights and specific gravities of 142 meteorites of which the fall has been recorded during the last hundred years, the average specific gravity of meteoric matter is deduced as being 3·69.

According to Emil W. Cohen,† the meteoric iron which has recently been found near Beaconsfield, Mornington County, Victoria, originally measured 30 by 30 by 15 centimetres, and after a portion of the thick coating of rust had been removed, it weighed 75 kilogrammes; it exudes much ferrous chloride, and is consequently liable to rapid alteration. It is an octahedral iron of coarse structure, with kamacite predominating. Crystals of schreibersite gave analysis I., agreeing with the ratio (Fe,Ni,Co) : P = 3·1585 : 1. Fine needles of rhabdite gave II., (Fe,Ni,Co) : P = 3·0533 : 1. The tænite gave III. after deducting some nickel-iron phosphide. Indistinct crystals of cohenite are irregularly distributed in the iron; after deducting a little schreibersite, which closely resembles cohenite in physical characters, it gave the results under IV. (Fe,Ni,Co) : C = 3·064 : 1. Nodules of troilite gave V., (Fe,Ni,Co) : S = 1 : 0·9901. Graphite, carbonaceous matter, and silicate grains are also present. The bulk analysis of the iron gave VI.; this corresponds with 98·07 per cent. of nickel iron.

	Fe.	Ni.	Co.	Cu.	C.	P.	S.	Cl.	Totals.	Specific Gravity.
I.	66·92	18·16	0·62	...	...	14·88	...	...	100·58	7·17
II.	[41·54]	42·61	[0·80]	...	...	15·05	...	...	100·00	...
III.	[50·92]	47·98	0·63	...	0·47	...	...	...	100·00	7·13
IV.	90·94	2·22	0·30	...	6·54	...	...	...	100·00	7·20
V.	58·07	4·34	1·52	...	...	trace	36·07	trace	100·00	4·74
IV.	92·56	7·34	0·48	0·02	0·05	0·26	0·04	0·01	100·76	...

* *Journal of Geology*, vol. v. pp. 126–130.

† *Sitz.-ber. Akad. Berlin*, 1897, pp. 1035–1050; *Journal of the Chemical Society*, vol. lxxiv. pp. 171–172.

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described, and named chalypite, from the telluric iron of Niakornak, near Jakobshavn in north Greenland, but since cohenite, Fe_3C, has recently been determined in the very similar iron of Ovifak, it seemed probable that chalypite would probably be identical with cohenite.

This iron carbide was isolated from 50·2847 grams of iron by the action of dilute hydrochloric acid; the nickel iron dissolved more quickly than meteoric irons; and there was a strong smell of hydrocarbons, but not of hydrogen sulphide. The material thus isolated (52·18 per cent.) consists of greyish-black, crystalline aggregates with good cleavage; analysis gave the results under I., agreeing with (Fe,Ni,Co) : C = 3·084 : 1. The portion soluble in the dilute hydrochloric acid (46·53) gave analysis II., representing approximately the composition of the nickel iron. The insoluble residue contained carbon (0·06 per cent.) with comparatively much copper sulphide, together with silicate grains, rust, &c. (1·23 per cent.).

The bulk analysis of the iron gave III.; previous analyses show variations from this.

	Fe.	Ni.	Co.	Cu.	C.	P.	S.	Residue.	Totals.	Specific Gravity.
I.	91·60	1·25	0·37	...	6·44	0·07	...	trace	99·73	7·5121
II.	97·03	2·09	0·71	0·02	...	0·11	0·04	...	100·00	...
III.	93·64	2·00	0·48	0·07	3·72	0·19	1·13	...	101·23	7·2704

Fresh fractures of the iron show a granular structure; on etched surfaces, the resisting cohenite is seen as bright, irregular patches, and Widmannstätten figures were not observed. Iron sulphide was not seen, but its presence is shown by the analyses. The great hardness of the iron is due to the large amount of cohenite present. Embedded in the rust of the iron was a small fragment of ophitic diabase, which is quite different from the Ovifak basalt.

According to W. Cohen,* the meteorite of Nedagolla, Vizagapatam district, Madras, is one of the few siderites, and the only ataxite, of which the fall has been observed; it fell on January 23, 1870. The structure is granular, like that of the Locust Grove and Forsyth Co. irons. Analysis gave the results under I.

The iron from Primitiva, Tarapaca, Chili, has also the granular structure of an ataxite; schreibersite and graphite are present. Analysis of

* *Ann. k. k. naturhist. Hofmuseums*, Wien, vol. xiii. pp. 119-126; *Journal of the Chemical Society*, vol. lxxiv. pp. 391-392.

of dynamite. The Mesabi ores are usually too soft to core with a diamond drill, and are generally sampled by washing out the material made by the churn drill. More accurate results for sampling are produced by dry drilling, and subsequently washing out the detritus with the minimum quantity of water. Great care must be taken to allow the ore to settle completely in the water.

Haulage and Hoisting Plant in the Chapin Mine.—An account of the haulage and hoisting plant at the Chapin Mine has recently appeared.* The ore trucks in the mine hold about 2½ tons each, and are hooked on to an endless chain running at the speed of 100 feet per minute. They are emptied by their own momentum into pockets, from which the skips are loaded through a door opened by a hand-wheel. At the surface the skip is tilted by guide rails, and discharges its load of 5 tons into waggons with side doors.

Mine Timber.—At Clausthal, in the Harz, the experiment has been made of using beech and fir instead of pine for timbering in stopes. Both kinds of wood were found to answer admirably where the rock pressure was not too great. As they are considerably cheaper than pine the economy effected by their use is considerable.†

A method of protecting mine timber is described.‡ The timber to be protected from subsequent destruction when in use is placed in a tank full of water. Unslaked lime is then well stirred in, and the wood allowed to stand in the solution for two or three months. It will have by that time been impregnated to a depth of about 1·2 inch.

Rock Drills.—Accounts are published § of comparative tests of the efficiency of hand drills as compared with machine drills at the Ischl and Hallstatt mines in Austria. Both hydraulic and electric driven drills were employed. The hydraulic drills were on the Harras-Tranzl system, and the electric rotating drills on that of Siemens and Halske. Somewhat variable results were obtained, but, under certain conditions, the hydraulic drills did 1·43 as much work as the hand drills, and the electric-driven drills three times as much work. Under other conditions, on the other hand, hand drills appear to have held their own.

An illustration of the Jackson hand-power drill has appeared.‖ The

* *Iron Ore*, through the *Iron Trade Review*, vol. xxxi. No. 10, p. 16.
† *Zeitschrift für das Berg- Hütten- und Salinenwesen*, vol. xlvi. p. 115.
‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvi. p. 443.
§ *Ibid.*, pp. 223-227.
‖ *Engineering and Mining Journal*, vol. lxv. p. 435.

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Halske's electric drills. From the practical point of view percussive drills have the preference given them when compared with rotary drills. Originally the solenoid method of construction was adopted in the case of the electro-percussive drill, but this gave unsatisfactory results. The author mentions several machines of this design. As electro-motors became better developed they were naturally utilised in connection with rock-drilling machinery as the motor-power. The new form of such drills as designed by Siemens and Halske, the author states, works very satisfactorily, only 25 or 30 per cent. of the power being required that is necessary for drills worked by compressed air. With an expenditure of one horse-power, 400 to 450 blows are struck per minute, and a hole is drilled in granite 1·38 inch in width to a depth of 3·15 to 3·54 inches. In sandstone a similar hole could be drilled in one minute to a depth of from about 8 to 16 inches. The motor drives the drill through flexible shafting. The author also refers to the application of electricity for various other purposes in mining work, such as for pumping, hoisting, and for ventilation.

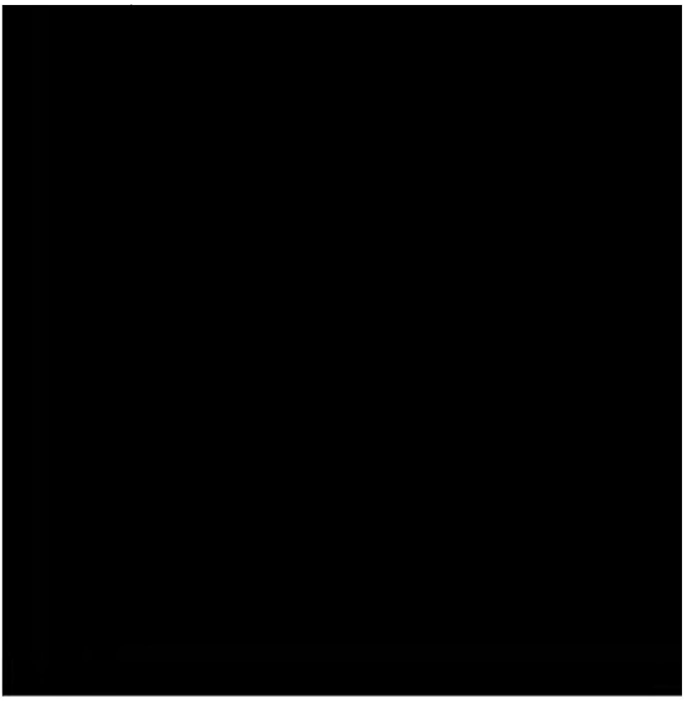
According to Erik Nordenström,* lengthened experiments have been made with Siemens and Halske's percussion drill at the Norberg iron ore mines. Full details are given as to the work done. The results are satisfactory. It is pointed out that this type of drill only requires 1 horse-power to work it, while compressed air drills require 5 horse-power, and other electric drills never less than 4. It is, too, easily manipulated, and the drills readily changed. One objection to it, however, is its great weight, which amounts to about 8 cwt. It is very long, and requires a wide working face. Then it is of complicated construction, and must be brought to surface at least once a week, not so much for repairing purposes as for a thorough cleaning.

Mining Ore Bodies of Uniform Grade.—E. F. Brown † describes the system of mining which has been in successful operation at the Pewabic Mine, Iron Mountain, Michigan, for a period of three years. About 600,000 tons of iron ore has been extracted by this system from a large body of highly siliceous, hard hæmatite ore of uniform quality.

A main level is driven in the hanging wall parallel with the ore body at a distance of 20 feet, and cross-cuts are driven to the foot wall, leaving blocks of ore about 80 feet long. Rises are put up near

* *Jernkontorets Annaler*, vol. lii. pp. 369-380.

† Paper read before Lake Superior Mining Institute, August 1898, through the *Colliery Guardian*, vol. lxxvi. p. 519.



(3.) *Mining Expenses.*—The general items of mining cost, breaking ore, sinking, drifting, timbering, &c., to represent the cost of underground work, hoisting and pumping being also included.

A total of the three general accounts, as above, shows the producing cost, including, however, only the regular cost accounts. The extraordinary expenditures are shown below this total line and include exploratory and depreciation accounts, as follows:—

(4.) *Exploratory.*—Exploring in mine—diamond drilling. Exploring outside—test-pitting and diamond drilling.

(5.) *Depreciation.*—Inventory, improvement, new construction.

Benefit Funds at Iron Mines.—In a Presidential address, W. G. Mather * describes the operation of the benefit funds in the Lake Superior iron ore mining industry. Relief and pension funds, housing of the men, condition of the mine, medical assistance, and education are amongst the topics dealt with.

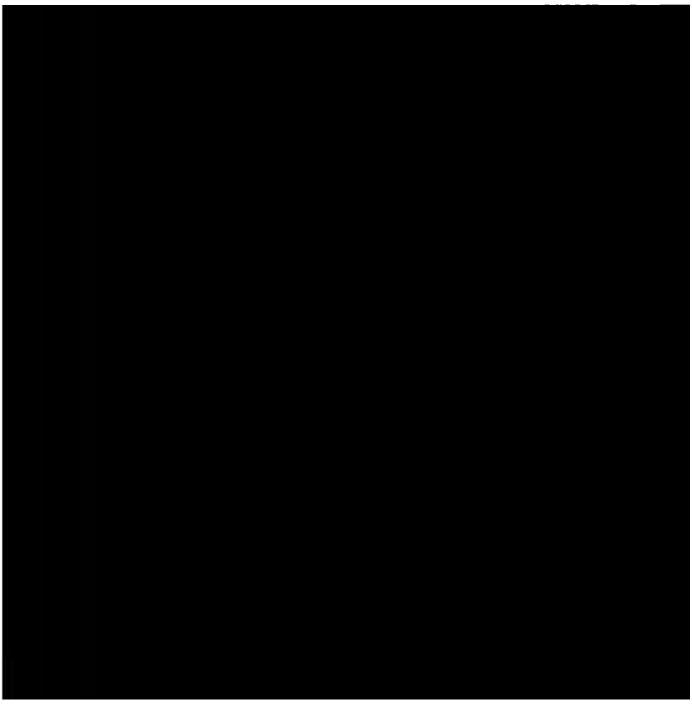
Ore-unloading Plant at the Kraft Ironworks.—The Kraft Ironworks of Kratzwilk,† near Stettin, have recently put up an ore-unloading and storage plant consisting of four machines. Each of these consists of a travelling trestle carrying an inclined boom reaching about 40 feet over the edge of the wharf. Ore or coal is lifted in trucks and run up this boom to the top, where it discharges into trucks. At the rear of the trestle is a travelling gantry with a span of 220 feet over the stock yard. The track on this gantry is inclined, so that the loaded truck runs down of its own accord to any desired point, where it is automatically emptied and returned by means of a weight lifted during its outward journey. This truck is automatic, and requires no attention whatever from the time of starting until its return to the workman for another load, the time of a trip being about 35 seconds. The hoists are driven by electric motors, and the capacity of the four machines is estimated at 50 tons an hour each.

Handling Iron Ore.—Illustrations have appeared ‡ of the ore-handling plant at Conneaut, Ohio. These show the ore storage docks and unloading machines, the M'Myler machine for transferring ore from ships to railway waggons, and the steam shovel for loading waggons from the stock piles.

* Lake Superior Mining Institute, August 1898, through the *Iron Trade Review*, vol. xxxi. No. 35, pp. 12-14.

† *Iron and Coal Trades Review*, vol. lvii. p. 597, with illustration.

‡ *Iron Trade Review*, No. 13, vol. xxxi. pp. 12-15.



rating apatite from magnetic iron ore at Lulea in Sweden). Group II. Magnetic separation of feebly magnetic ores (Wetherell's concentrator at the Grillo Zinc Works, and the results obtained with it elsewhere).

The Dellvik-Grondal magnetic separator for enriching fine iron ore slime has been employed for some years at Pitkaranta, in Finland. According to the *Wermlandska Annaler*, the raw ore is ground in water by means of a ball-mill, which is capable of converting daily, with an expenditure of 15 horse-power, from 30 to 60 tons of moderately hard iron ore of about 2-inch lumps into fine powder. The material is enriched from an iron content of about 25 per cent. to one of 66 to 68 per cent., while the waste only contains 1 per cent. of iron, not including iron silicate. The separator has the appearance of two rather high drums, or barrels, which in one place are cut off by vertical planes and brought together. In one barrel revolves the separator, consisting of a vertical shaft fitted with cast iron sheaves placed 2 inches apart, which derive their magnetism—strongest at the upper sheave—from electric winding; and in the second barrel, corresponding with the cast iron sheaves, small iron plates revolve at the distance of from 1½ to 2 millimetres from the sheaves. The ore, formed into slime by water, runs directly from the ball-mill, and trickles off from the upper conical portion of the separator on to its periphery. Particles not containing iron are washed away directly by a further quantity of water, allowed to flow into the separator, while the ore is attracted by the periphery of the sheaves to which it adheres. The sheaves set up magnetism of the opposite name in the small iron plates of the barrel, owing to which the grains of iron ore leap over and immediately afterwards fall to the bottom, because the magnetism decreases with the distance from the separator sheaves. The iron ore thus obtained in the form of powder is made, without any addition, into briquettes, which are burnt at a temperature of 800° C. and melted in the blast-furnace.

E. Ferraris * describes a new magnetic separating plant. This has been erected at Monteponi, and was put into operation at the commencement of 1898. The material to be treated consists of a mixture of iron and zinc ores. This is put into a calciner and calcined. From 2 to 3 per cent. of small coal is also charged in with the ore, so that partial reduction also ensues. After the calcination the ore mixture is passed to a trommel and divided into six sizes, which are

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvi. pp. 347-348, with two illustrations.

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working. The second chapter is devoted to iron ore dressing, the various ore washers and magnetic concentrators being fully described and illustrated. The third chapter deals with the comminution of iron ore. The remainder of the volume deals chiefly with the roasting of iron ores.

Large Rock Crusher.—A considerable number of Gates crushers, with a capacity of 200 tons hourly, are now in use, chiefly for crushing limestone for blast-furnaces. These machines stand about 12 feet high and weigh about 90,000 lbs. The crusher head is of cast iron, 40 inches high, 22 inches in diameter at the top, and 38 inches at the bottom. The chamber is 36 inches deep, and the top and bottom diameters are 56 and 41 inches. The speed of the head is about 140 gyrations per minute. Illustrations are given of the plant for handling the material to be crushed.*

Graphic Records of the Screening of Crushed Materials.—C. de Kalb † gives the results of a preliminary investigation into the behaviour of rocks and ores when subjected to crushing under different conditions. The crushed material is passed through sieves of different meshes, and the weight remaining on each is taken. The weight and size are used as coordinates for plotting. Contrary to expectation the curves presented practically identical characteristics for different materials when crushed under similar conditions, and only by varying these conditions were variations in the curves obtainable. It is also found that successive crushing to smaller sizes did not augment the quantities of finer products so long as the machines applied the crushing force to ore particles in the same manner.

Briquetting Iron Ore and Flue Dust.—Illustrations are given ‡ of a White press which is used for compressing powdered ore, flue dust, and similar materials into briquettes for use in the blast-furnace. The machine consists of a large mixer mill for incorporating the mixture, which falls through holes in the pan into a mould disc, which is worked [illegible] actuated plungers.

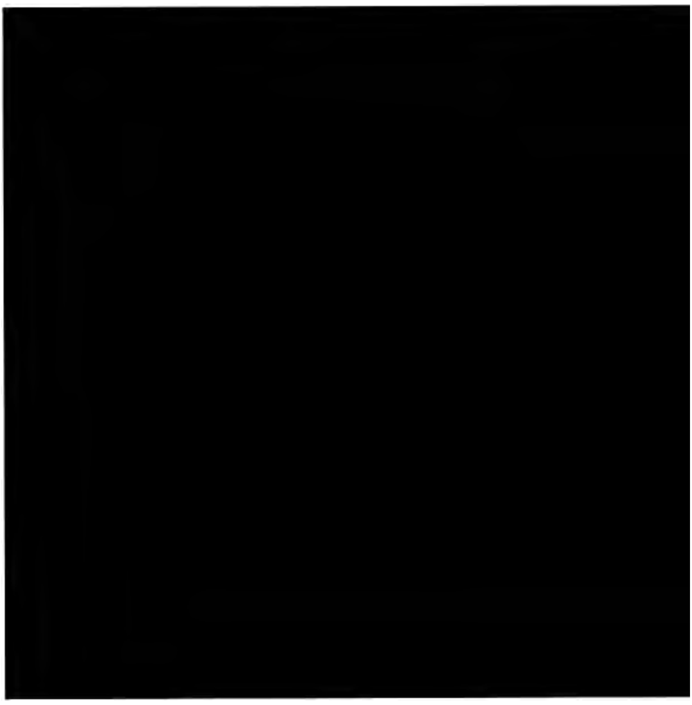
[illegible] states that a plant of this nature is in use at the [illegible]

* [illegible] pp. 35–39.

† [illegible] *Mining Engineers*, Buffalo Meeting, 190[illegible]

‡ [illegible] 421.

§ [illegible] Supplement, January 7th, p. 31.



REFRACTORY MATERIALS.

Fireclays. — H. A. Wheeler* describes the fireclay resources of Missouri, of which there are two classes. The flint or non-plastic clays or rock clays occur in isolated pockets or basins in silurian limestones; and the plastic clays occur in continuous beds or sheets in the coal-measures and tertiary formations. They are both extensively used, and have the following percentage composition:—

	Flint Clays.	Plastic Fireclay.
	Per Cent.	Per Cent.
Silica	48 to 50	48 to 70
Alumina	38 to 42	30 to 38
Combined water	12 to 14	7 to 13
Ferric oxide	0·2 to 0·8	0·2 to 5·0
Lime	0·2 to 1·0	0·1 to 2·0
Magnesia	0·1 to 0·6	0·1 to 1·0
Alkalies	0·1 to 2·0	0·2 to 1·4

According to J. E. Todd, the State Geologist, South Dakota is rich in fireclays, extensive deposits of a good quality occurring in the Dakota formation that forms the edge of the Black Hills. At Rapid City, [illegible] a thick bed has been worked for several years.

E. A. Smith† describes the fire and other clays of Alabama.

[illegible] has also published an article on fireclays; and the [illegible] fireclays of Borna, near Leipzig, are described by K. Naegeli.§

Testing Fireclays. — [illegible] describes a modification of Bischof's method of determining the fusibility of clays as applied to [illegible] clays and the resistance of fireclays to fluxes. In

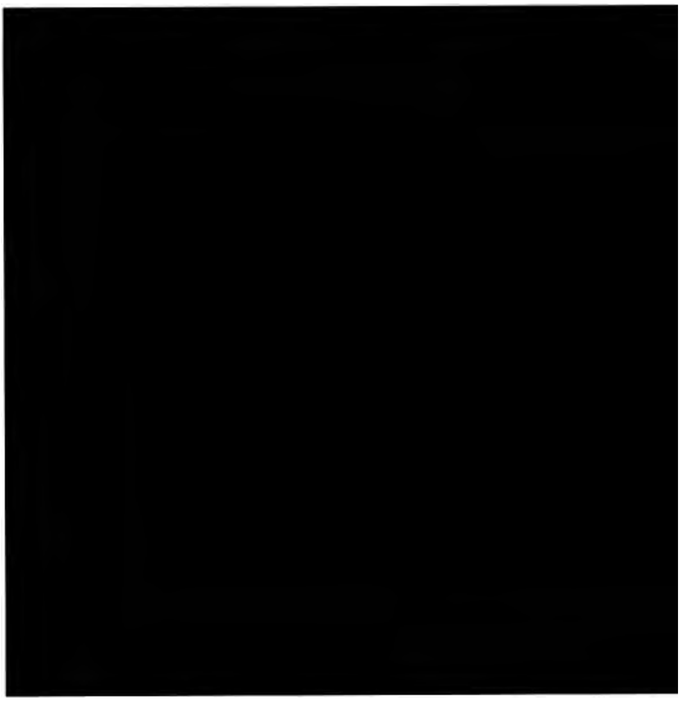
[illegible]

[illegible]

[illegible]

§ [illegible]

[illegible] *Institute of Mining Engineers,* [illegible]



in several provinces, and of a composition well suited for the manufacture of basic bricks. The following are some analyses :—

No.	$MgCO_3$.	$CaCO_3$.	$Al_2O_3+Fe_2O_3$.	Insoluble Residue.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
1.	40·88	55·9	0·78	2·41
2.	39·40	57·7	0·42	2·80
3.	37·80	60·9	0·66	0·76
4.	37·50	61·2	0·53	1·27

Chrome iron ore is also met with. Analyses of this material have shown—

Cr_2O_3.	FeO.	Al_2O_3.	MgO.	SiO_2.
45·82	15·31	20·40	16·50	0·53
58·94	14·42	11·10	15·60	0·20

Fire-Bricks.—P. Kirkup* describes the manufacture of fireclay goods from the under-clays of thin coal-seams. The clay is picked over by hand to separate pyrites and coal, and passed through a mill under two rollers of 6 tons each. The crushed clay is screened in revolving trommels with four to eight meshes per inch, then mixed with water and pugged. Fire-bricks of this material are moulded by hand, as machinery appears to make them too dense. The bricks are dried preferably with the aid of warmed air, and burnt in kilns of several types. The oblong or Newcastle kiln is largely used.

S. Cattier † describes in detail the manufacture of bricks from coal-measure shale. His paper is illustrated by dimensioned drawings of the Hoffmann kiln.

Austrian Graphite. — Graphite from St. Lorenzen, in Styria, analysed by C. von John ‡ gave the following results :—

Carbon.	Ash.	Moisture.	Combined Water.
66·22	30·55	1·60	1·63

Graphite from Brezinck, near Gewitsch, in Moravia, yielded—

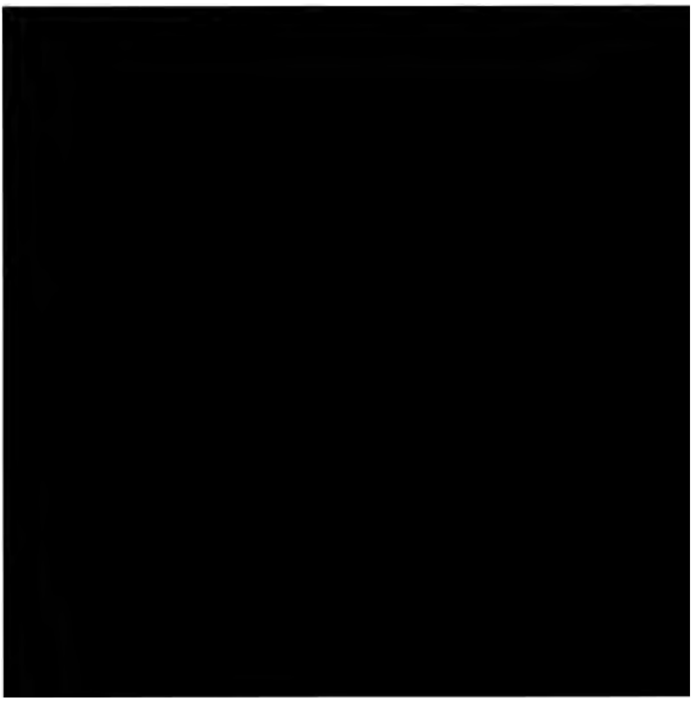
Carbon.	Ash.	Water.
7·40	84·20	8·35

In the *Transactions of the Bohemian Chemical Society* F. Kovar gives analyses of some minerals from the graphite mines at Maly Tresny,

* *Transactions of the Institution of Mining Engineers*, vol. xv. pp. 45–66.

† *Revue Universelle des Mines*, vol. xlii. pp. 257–264.

‡ *Jahrbuch der k. k. geologischen Reichsanstalt*, vol. xlvii. p. 746.



required a white heat before it was properly decomposed, whereas an American bauxite that contained

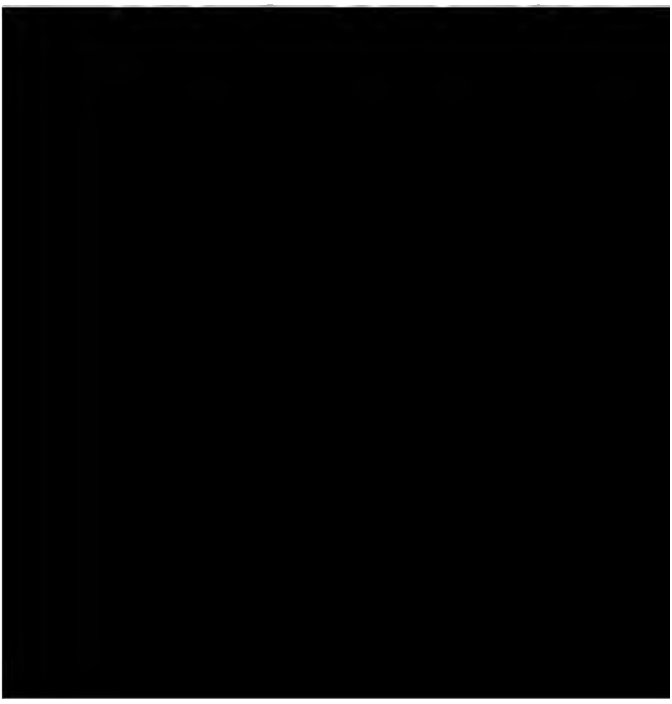
Al_2O_3.	Fe_2O_3.	SiO_2.	TiO_2.	H_2O.
59	2	3	4	32

only required quite a low temperature to effect the same result.

At the Gute Hoffnungshütte, the author observes, bauxite is used in admixture with clay, lime, or burnt dolomite for lining Bessemer converters. Other uses are also mentioned. The production of this mineral appears to be steadily increasing.

W. M. Brewer * describes the condition of the bauxite industry in Georgia and Alabama.

* *Engineering and Mining Journal*, vol. lxv. p. 405.



Magdeburg Association of Boiler Users. The values were calculated from the analyses by the aid of the Dulong formula, and have received, the author observes, less attention than they deserved, and he now deals with this subject himself. In the case of the earthy brown coals of Central Germany, the percentage of moisture present is of the greatest importance as far as the heating value is concerned. The value of the coal raised in Germany is about twelve times that of the brown coal also raised, and the result is that the latter coal is not sufficiently dealt with in treatises on fuels. This earthy brown coal possesses the property of taking up water in such a quantity that this may reach 60 per cent. of the total weight. The result is that a 10-ton truck-load of brown coal might really consist of only 4 tons of the fuel, and 6 tons of water. On the other hand, 10 per cent. of water in a bituminous coal would be considered exceptionally high, and is indeed of rare occurrence. As a rule the percentage is less than 4, and usually it is only from 1 to 2. Good lump coal will let the water drain away when it reaches 2 or 3 per cent., while earthy brown coals will often feel scarcely moist even when they contain 50 per cent. of moisture. In determining the calorific value of a brown coal, the percentage of water it contains must therefore also be ascertained. This is not an easy matter either, as such brown coals often undergo decomposition with great readiness. Thus some coals give off a marked smell even when their temperature is only 50° C. The author considers that it is consequently inaccurate to first fully dry the fuel, and then to determine the calorific power of the dried fuel. Even at ordinary temperatures the composition of this fuel is constantly changing, oxygen being absorbed, while other constituents escape. A portion of the water present in brown coals exists in combination, and is not free. The author refers to a number of statements by different authors on this subject, and then deals with the difficulty of determining the moisture in further detail. Even bituminous coal undergoes change of composition when dried at 100° to 110°, as the following results show as stated by Fischer :—Finely-powdered Bantorf bituminous coal, when heated for three hours, lost 1·83 per cent. ; and when kept over-night above water, became again 2·59 per cent. heavier. Of this same coal, 2·153 grammes, heated to 100° to 105° C. for three hours between watch-glasses, diminished in weight to 2·060 grammes, a loss of 4·35 per cent., and subsequent experiments showed the following results :—

above, but Cal. power = $80\ C. + 290\ (H - \frac{1}{8}O) + 25S - 6W$ being the water present. The author gives a large number—forty in all—of such determinations made in the case of Central German earthy brown coals, and from these he calculates the following average result for this kind of coal. He gives the percentage composition as—

Carbon.	Hydrogen.	(O+N+S).	Ash.	Moisture.
32·0	2·7	13·5	6·5	45·3

	Calories.
The lower calorific value	2690
The calorific value for the coal completely free from water	4920
The calorific value of the coal with 30 per cent. moisture present	3450
The calorific value of the coal with 45 per cent. moisture present	2705

In the case of the perfectly dry brown coal, the maximum shown, except in the case of one single sample, was 5947 calories, and the minimum 4374. The percentage of ash varied from 3·89 to 13·22, and that of moisture from 15·60 to 53·0. The following are the highest and lowest analyses, as far as the percentage of carbon in the fuel is concerned :—

	Carbon.	Hydrogen.	O+N+S.	Ash.	Moisture.
Maximum . .	54·33	4·50	17·02	7·72	16·38
Minimum . .	27·29	2·51	11·76	10·30	48·14

The calorific values of these fuels in the dry state were respectively 5947 and 4429.

Pyrometry.—J. Kersten * describes and illustrates the pneumatic pyrometer devised by Uehling and Steinbart.

According to A. Stansfield,† in obtaining photographic records of the readings of thermo-electric pyrometers, the range of measurement is limited by the size of the photographic plate. For long ranges of temperature, the sensitiveness of the galvanometer must, therefore, be small. When it is desired to examine the temperature changes in detail, as, for instance, at the melting-points and freezing-points of metals, it is necessary to employ some device for giving a more open scale for the short temperature ranges that include those particular points. For this purpose two galvanometers are arranged in parallel, and so that they have their deflections recorded on the same photographic plate. The less sensitive galvanometer covers the entire range of temperature

* *Revue Universelle des Mines*, vol. xliii. pp. 44–62.

† Paper read before the Physical Society, March 1898.

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Ruthin, by A. Strahan.* This supplement contains records of borings put down in the reclaimed portion of the estuary of the Dee, and these are of importance as proving the presence of upper coal-measures which do not appear at the surface, and were not previously known to exist in Flintshire or west Cheshire. In this region the middle coal-measures are the productive strata, and the new information shows that the upper coal-measures may underlie much or all of the Cheshire Trias, and would consequently have to be penetrated in winning the coal.

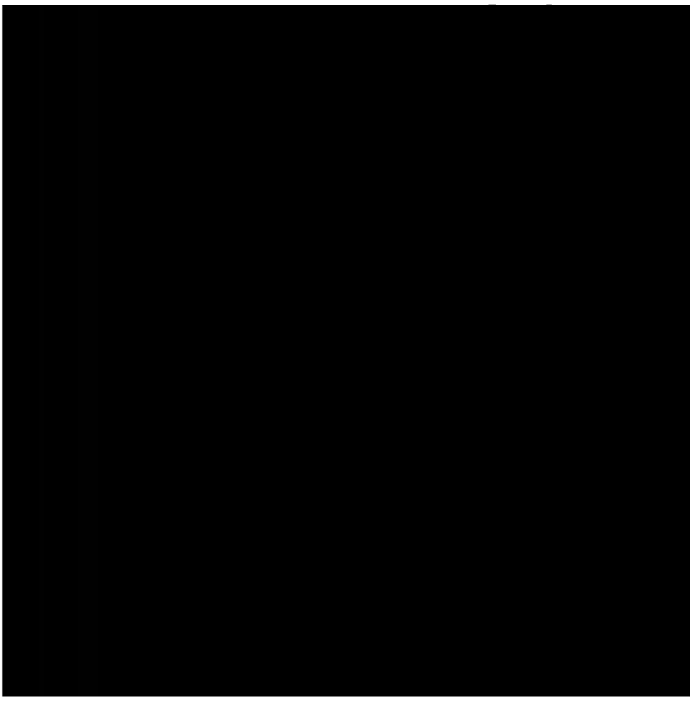
Coal in the South of England.—W. H. Hudleston,† in a presidential address, refers to the probability of finding workable coal east of the proved Somersetshire field. The question of coal south of the Mendips is too speculative on account of the chances of deterioration of the coal-measures in that direction. But in view of the forthcoming meeting of the British Association at Dover, the question of finding coal to the eastward of Bath becomes a specially interesting subject for discussion. It is also a matter of some consequence whether the hidden basin or basins belong to the meridional or to the east and west system of flexures. The latter is most likely to be the case. The vale of Pewsey has been mentioned as a suitable locality for boring along the line of the recognised axis. But prospectors should bear in mind the warning of Ramsay, that the basins containing coal are but few in comparison with the number of basins throughout the palæozoic rocks. No doubt the line indicated is more favourably situated for coal exploration than the eastern counties. The unsuitability of East Anglia as a field for coal-prospecting was insisted on in the author's second anniversary address to the Geological Society, and the results seem to have been very much what might have been expected. If coal is to be found beneath the secondary rocks, the line of search should be carried through the counties of Kent, Surrey, Berkshire, and Wiltshire, though the three latter counties have hitherto been content to leave their underground riches unexplored. The Kent Coal Exploration Company is doing some good work with a reasonable chance of success; though if they wish to find coal sufficiently near the surface they had better adhere as much as possible to the line of the North Downs, since operations on the Sussex side are only too likely to be within the influence of the Kimmeridgian gulf, which was proved to exist at Battle.

R. Etheridge ‡ deals with the "Relation and Extension of the

* *Nature*, vol. lviii. p. 628.

† Paper read before the Geological Section of the British Association, September 1898.

‡ *Ibid.*



the coalfield of the north of France, in which he shows its remarkable analogy in structure to the Cretaceous basin of Fuveau.

Austrian Coal.—C. von John and C. F. Eichleiter * give the results of analyses of 30 specimens of Austrian coal, and of 17 specimens of Hungarian coal.

K. A. Weithofer † has published a detailed account of the geology of the Schatzlar-Schwadowitz section of the Lower Silesian and Bohemian coalfield.

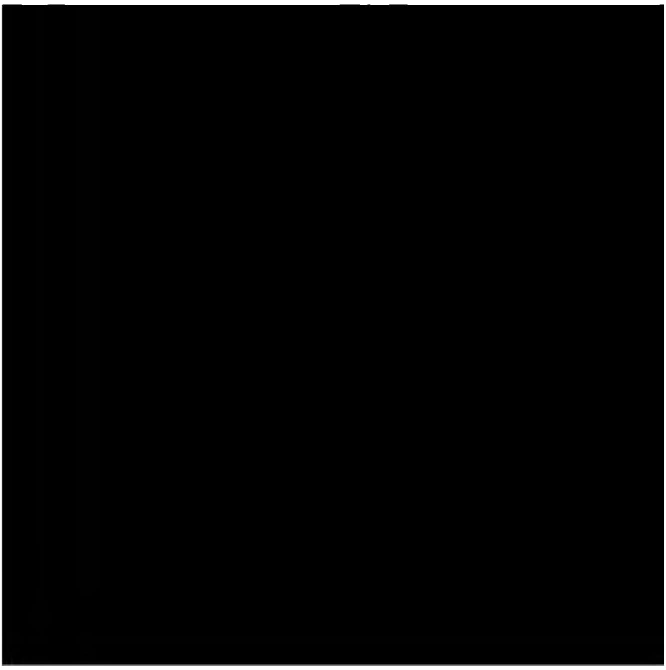
The Coal Industry of the Rhenish Westphalian Provinces.—[illegible] ‡ gives details of the coal industry of the Rhenish Westphalian Provinces. Numerous tables, chiefly dealing with the capital and labour employed and with the yield of the collieries, are appended. Some extracts are given by H. Hall. §

Brown-Coal Discoveries in Saxony.—Borings that have been put down near Leipzig are stated to have discovered at Wachau a seam from 10 to 11 yards in thickness. || At Stockheim, near Lausigk, a seam from 5 to 7 yards in thickness has been met with at a depth of from 27 to 38 yards. At Hartmannsdorf, near Borna, 11 boreholes have been put down, and have shown the presence of a seam of brown-coal from 13 to 15 yards thick. At Golzern, near Grimma, borings have shown the existence of a brown-coal seam some 7 yards in thickness, and extending over an area of 82 acres, and at a depth of from 26 to 37 yards. Other seams are also mentioned as having been discovered elsewhere, some of which are of very considerable thickness, one being about 14 yards and another 11 yards thick.

Lignite in Greece.—According to Zengelis ¶ lignite is now mined in three places in Greece. Of these the most important is Kumi which supplies 15,000 tons yearly.

Coal in Hungary.—A. Gesell ** discusses the geology of the Fünf-

* *Jahrbuch der k. k. geologischen Reichsanstalt*, vol. xlvii. pp. 737–745.
† *Ibid.*, pp. 455–478.
‡ Consular Reports, Miscellaneous Series, No. 454.
§ *Transactions of the Manchester Geological Society*, vol. xxv. pp. 569–577.
|| *Jahrbuch für das Berg- und Hüttenwesen im Königreiche Sachsen*, 1897, p. 146.
¶ Paper read before the International Chemical Congress, through *Engineering*, vol. lxvi. p. 396.
** *Ungarische Montan-Zeitung*, vol. iv. No. 11.



the five years 1892–1897 inclusive. In this report the Kusnezk coal-beds in the Government of Tomsk are recognised as a reliable source for Western Siberia: they are 27,000 square miles in extent, and contain the extraordinary rich mines of Koltschuginsk. Beds of anthracite are also found here. Other coal-beds were found in Western Siberia and in the Steppes, and of these the most productive proved to be the Karagandinsch and the Kau-Tcheku deposits. Mention also is made of the coal-beds at Chibas-Tus, Nazarjevsch, and at Kurbatov, near Atchinsk. This coal lies far distant from the line of railway, and the unavoidable outlay involved in transporting it to the railway will considerably increase its cost. More favourable results were obtained in this respect near the station of Sudshenka, on the Central Siberian line, where seams of coal of good quality were found in the neighbourhood of the line, suitable for use in locomotives. Geological investigations were also undertaken in the section of the Central Siberian line, in the rich coalfields of Kuskunskija, Kubekovskija, and Antropovskija, in the Government of Yenisei. The Central Siberian surveying section also discovered a deposit of brown coal in the Trans-Baikal district, near Lake Baikal, at Myssowaja. As to the results of the Eastern Siberian geological survey, the presence of coal was established at the following places:—Near the village of Tcheremchovskoje, on the river Angora, in the Government of Irkutsk; at Wyssokaia Dubrava on the river Belaja, in the Government of Tomsk, and along the railway embankment from the town of Nijni-Oudinsk as far as the village of Kimilteiskoje. Of these coal-deposits the first-named are especially worthy of attention. The work of this Commission is also described by Venukoff. *

In the year 1888 the Russian Government sent a geological expedition to Eastern Siberia, to the coast district known as Ussuriland, with a view to examine the country for coal in the vicinity of the harbour of Vladivostock.† It was specially desired to search not merely for any kinds of coal, but particularly for coal suitable for steam-raising purposes, so as to free the Russian Eastern Asiatic squadron from its former dependence on Cardiff coal. Very satisfactory results were obtained, a broad zone of coalfields, reaching up to 126 miles in width, was discovered crossing Southern Ussiriland, of which, however, owing to want of transport facilities, only some 12 square miles in the neighbourhood of the Ssutschan river is workable. A portion of this

* *Comptes Rendus de l'Académie des Sciences*, June 13, 1898.
† *Stahl und Eisen*, vol. xviii. p. 439.

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sumption is inappreciable, practically the whole output is used for steamships, railways, and factories. The results of the examination of the various coals have been plotted in curves, and a table of previously published analyses of Indian coal is also given. The coals vary greatly in composition and in quality. Most of them are quite suitable for ordinary purposes, whilst some of the samples from Bengal and Central India are of excellent quality, quite equal to that of many English or Welsh coals. The Bengal coal is that most largely mined, and a great deal of it is serviceable steam coal. Many samples cake well and contain but little sulphur. The coke made from this coal appears, therefore, to be suitable for iron-making.

A summary of this report is given by B. H. Brough,* who notes the omission of the analyses of Hyderabad coal, recorded in J. P. Kirkup's monograph on the Singareni coalfield.

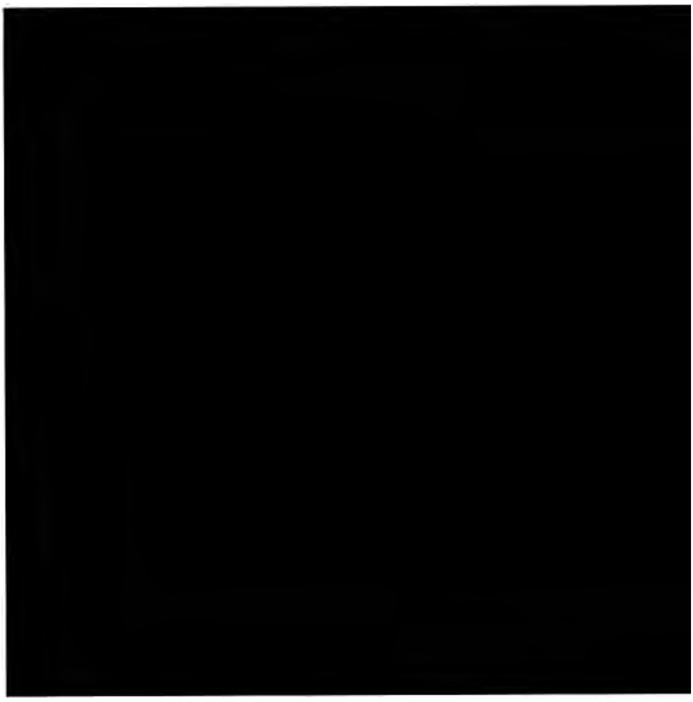
Coal in Newfoundland.—According to D. W. Prowse † there are three coal areas in Newfoundland—Grand Lake, St. George Bay, and Codroy. The two latter are known to be extensive coalfields producing very superior coal. It is probable that in the near future the Codroy coal will be worked. It is the best steam coal, and is very near Port-aux-Basques, the terminus of the railway.

The completion of the branch railway to the coalfields of Grand Lake is probably the most important event of all, whether viewed from a local or an Imperial standpoint. It is the nearest coal-supply to England across the Atlantic. It gives Britain an unrivalled supply of fuel for her ships of war 500 miles nearer home than Halifax. The coal is bright, clean, and hard, like Wharncliffe Silkstone coal. It burns with a white ash, and has been tested on the local railway with excellent results. Coal-mining and exploration have only been carried out on a very small scale over the 50 square miles of the Grand Lake coalfields. The largest output so far is from the pit at the end of the branch railway, and investigations have shown that the coal-measures and workable areas of coal extend much further than was at first supposed. The opinion formerly held that the coal in Newfoundland was only the tail end of the Cape Breton coal is now rejected.

Coal in Cape Breton.—E. T. Moseley has presented to the Mining Society of Nova Scotia an account of the recent discovery of coal near Cochrane's Lake, Cape Breton. The seam is 6 feet thick, and underlies

* *Nature*, vol. lviii. p. 380.

† *The Times*, August 16, 1898.



which would be important for the reduction of ores in the mining district of Northern Arkansas.

Coal in Colorado.—Arthur Lakes * describes the El Paso coalfield, near Colorado Springs. The coal yields 49 per cent. of fixed carbon. It is not, however, a coking coal.

Coal in Michigan.—A pamphlet has been published describing the coalfields of Saginaw, Michigan. Until about a year ago these coalfields received little attention and were not considered important. In 1897, however, several companies were organised and operations begun. The pamphlet gives an account of the different companies and their work, and takes a favourable view of their future.

Coal in Ohio and West Virginia.—E. H. Coxe † discusses the competition of West Virginia with Ohio coal, and gives many particulars affecting the mining and properties of the coal in those States.

Coal at the Omaha Exhibition.—W. B. Phillips ‡ describes the coal and coke shown at the Omaha Exhibition. The exhibits are grouped under the separate States. The Jeffson Coal Company, of Alabama, shows some good coke made from slack coal from the Stein washer. The analysis given is—

	Per Cent.
Moisture	0·75
Volatile matter	0·75
Fixed carbon	89·00
Ash	9·50
Sulphur	0·70

When the Robinson washer was used, the ash in the coal was rarely less than 14 per cent.

The Colorado coals are well exhibited. The specimens are of uniform size mounted on blocks of wood, and have full analyses appended. Anthracite from Gunnison County, Colorado, contained—

	Per Cent.
Carbon	87·56
Hydrogen	3·11
Oxygen	2·69
Nitrogen	1·29
Ash	4·15
Sulphur	0·89

Numerous analyses of bituminous coal from Colorado are given.

* *Mines and Minerals*, vol. xviii. pp. 483–484.
† *Engineering and Mining Journal*, vol. lxvi. p. 434.
‡ *American Manufacturer*, vol. lxiii. pp. 49–50.

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Pennsylvania the influence of the geology upon the topography is similarly observable on a much larger scale.

Coal in the Rocky Mountains.—R. M. Hosea* publishes a description of the methods of mining and preparing anthracite in the Rocky Mountains. The seam worked at a mine he describes is thin, 4 to 4½ feet, but of very fine quality, hard and glossy. Its average composition is—

	Per Cent.
Fixed carbon	87·51
Volatile matter	7·62
Moisture	0·72
Ash	4·15

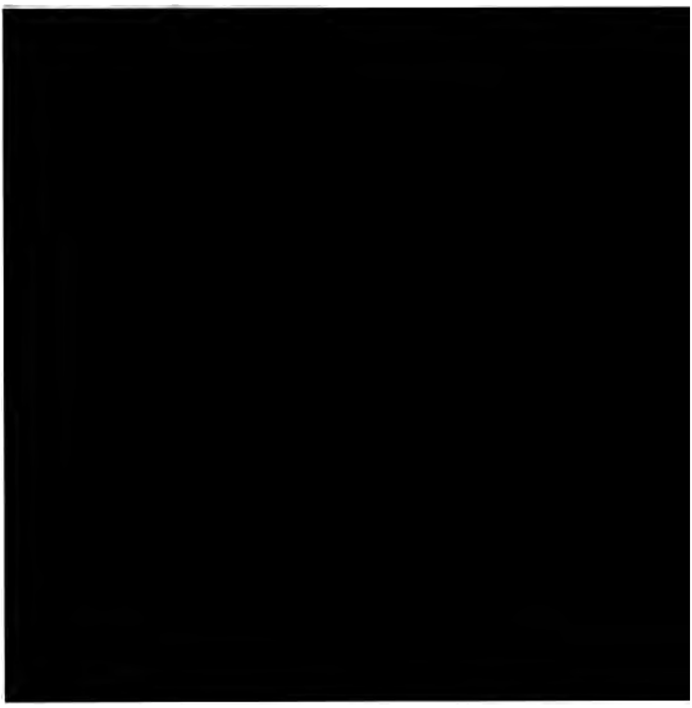
G. M. Dawson, Director of the Geological Survey of Canada, notes the industrial development of the Crow's Nest coalfield in the Rocky Mountains. At Fernie he found 100 coke-ovens being erected to supply the smelting works in the Kootenay district. A branch line of 5 miles connects the collieries with the main line.

Coal in Washington.—Surprise is expressed that the coal used by the United States Government on the Pacific Coast is obtained from British Columbia instead of from Washington. As a matter of fact the Washington coal is not of such good quality. British Columbia coal contains 86 per cent. of fixed carbon, 9 per cent. of volatile matter, and 2 per cent. of ash, whereas the Washington coals run from 62 per cent. of fixed carbon down to 53 per cent., with 20 to 30 per cent. of volatile matter, and 14 to 11 per cent. of ash. The following are analyses of Washington coals:—

	Fairhaven.	Wellington.	Roslyn.
	Per Cent.	Per Cent.	Per Cent.
Moisture	0·31	1·60	1·45
Non-combustible volatile matter	2·09	6·97	30·82
Combustible volatile matter	20·17	25·30	...
Fixed carbon	62·39	56·40	53·65
Sulphur	0·14	0·20	0·15
Ash	14·88	9·52	11·94
Phosphorus	0·24	...	0·01

Use of Anthracite in the Navy.—An important communication has been made by W. K. Lord relative to the use of anthracite in the United States Navy. He is opposed to the use of boilers burning

* *Mines and Minerals*, vol. xviii. pp. 529–533, vol. xix. pp. 7–8.



Describing the mineral resources of Chili, Wiener * points out that mineral fuel is not absent, for in the south of Chili there are a fairly large number of mines of brown coal. The following analyses give an idea of the composition of the fuel:—

	Buen Retiro.	Lota.
	Per Cent.	Per Cent.
Fixed carbon	48·20	53·20
Volatile matter	40·80	40·20
Water	4·80	5·00
Ash	6·20	1·60
Total	100·00	100·00

Anthracite in Peru.—The Peruvian anthracite deposits are reported on by the Bureau of American Republics. The deposits are on the summit of the Andes, in the province of Hualgoyoc. Surveys are now being made for a railway from Pacasmayo on the coast to the coalfield, a distance of 121 miles. It is estimated that 2,000,000 tons can be mined annually and delivered at the coast for 8s. a ton.

F. G. Carpenter † states that both anthracite and lignite occur on the east and west slopes of the Andes, and that the deposits are to be developed.

Coal in South Africa.—The British Vice-Consul at Chinde has made a report ‡ to the Foreign Office on the coalfields of the Upper Zambesi. Steps taken to ascertain if the coal was of sufficiently good quality were so satisfactory that consignments are now being brought to Chinde by almost all the steamers visiting Tete.

A description of the collieries in the South African Republic has recently appeared. Amongst those mentioned are those at Brakpan, De [illegible], and Springs. The Brakpan farm covers some 4000 acres, and on it are two shafts about 200 feet deep. The upper 4-foot seam is not worked, and all the coal is produced from the lower seam, which has [illegible] seam [illegible] surmounted by 14 feet of lower quality. [illegible] there are two seams 12 and 20 feet in thickness [illegible] and 14 feet are good. The seams are [illegible]. Brief descriptions of the hauling, screening, and [illegible] given. §

* [illegible] pp. 676–681.
† [illegible] vol. xiii. p. 158.
‡ [illegible] No. [illegible].
§ [illegible] vol. xxvi. pp. 119, 151, 200, &c.

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Coal Testing by the Röntgen Rays.—The sphere of usefulness of the Röntgen rays is gradually widening, and is now being extended to the testing of coal. According to H. M. Couriot,* carbon, in all its forms, is exceedingly transparent to the rays, while silica and silicates are opaque. By placing a lump of coal between a Crookes tube and a fluorescent screen, all the dirt forming parts of the fuel can be detected. In this manner the author has tested anthracite and bituminous coal, lignite, coke, and block fuel. The conglomerate character of the latter fuel is clearly shown; and in coke the particles of iron sulphide show as black spots on the screen. Rough lumps of coal, 1½ inch to 2 inches thick, may be used, with an exposure of five minutes, using a coil having a 10-inch spark.

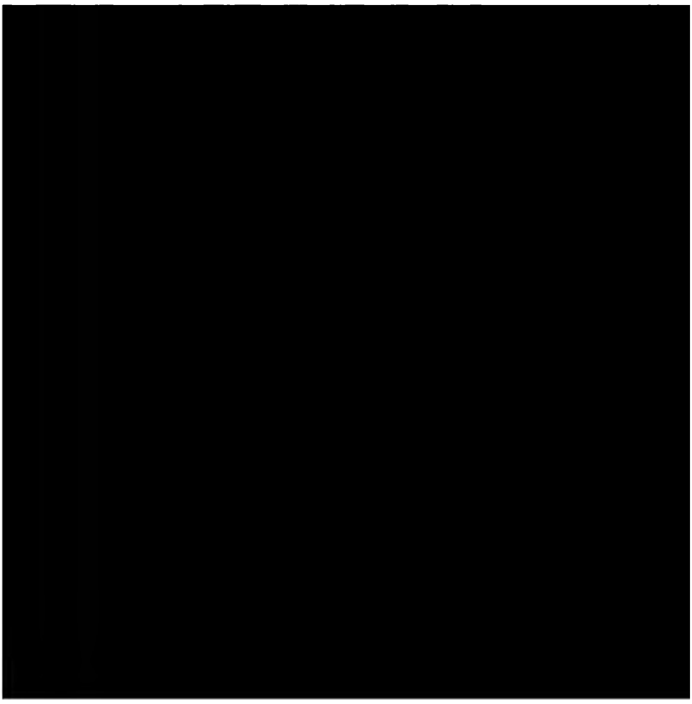
Elements in Coal.—A. Jorissen † has examined dust collected from the chimney of some stoves in which coal of the Liége district had been burnt. In this material were found selenium, lead, arsenic, molybdenum, bismuth, copper, nickel, cobalt, and zinc.

The Coal Question.—In dealing with some of the mechanical and economic features of the coal question, T. Forster Brown ‡ notes the difficulty of inducing the public to realise the supreme importance of the fact that it is only the best and cheapest of our coal resources which supply the existing output. Allowing for a small gradual increase of output from deep and inferior seams during the next fifty or sixty years, and assuming an average output for fifty years of best coals within a depth of 2000 feet at 220,000,000 tons per annum, they would exhaust eleven-fifteenths of the best resources about the year 1950. It is apparent, however, that at the end of fifty years they would still have coal resources remaining workable, at a gradually increasing cost, it is true, but sufficient for the supply of the nation at an average output of 250,000,000 tons a year for upwards of a period of 250 years. That this extra cost would gradually increase year by year after the best and cheapest coals were exhausted, is undoubted, however successfully the skill of the mining and mechanical engineer might be brought to bear in mitigating this effect, and unless additional measures could be adopted outside the province of the engineer to counteract it, by cheapening the carriage of the coal on the surface and

* *Industries and Iron*, vol. xxv. p. 132.

† *Annales de la Société Géologique de Belgique*, vol. xxiii. p. 105.

‡ Paper read before the Mechanical Section of the British Association, September 1898.



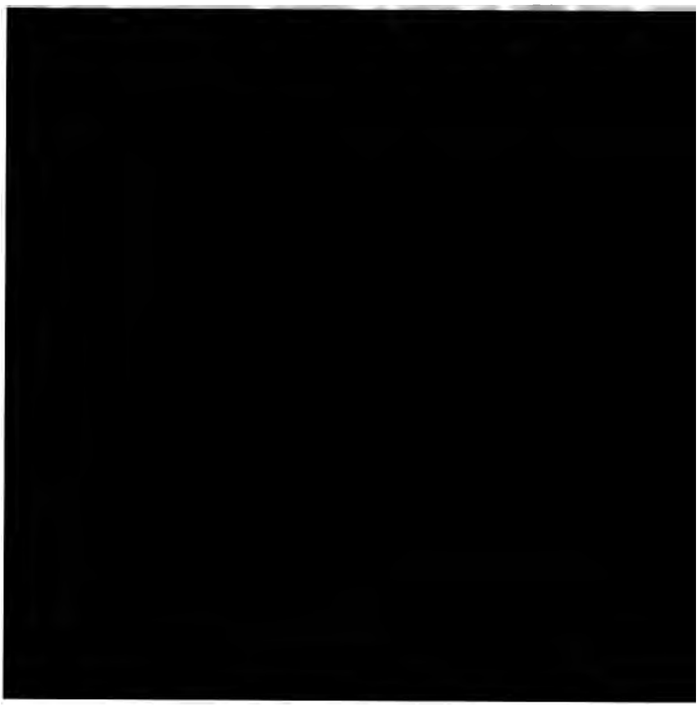
third of the cost of charring in stacks in the usual way. Each kiln contains four, six, or eight chambers, which are charged with wood through an opening in the roof from an overhead conveyor. The wood is in the form of round logs or slabs, and other refuse from the saw-mill, the length being preferably equal to the width of the chamber. Below the bottom of each chamber there are two fire-boxes, one on each side of the kiln, and two flues for the outgoing gases on the side of the chamber opposite the fire-boxes. The chambers are provided on both sides with discharging doors, which are made in three parts in order to make them light and easily handled. The bottom of the kiln inclines from the centre to the sides to facilitate the discharge of charcoal, and is also slightly dished, so that the condensed water may flow out at the centre of the opening. The products of combustion pass from the fire-box through a number of small ports into the chamber above, and after passing over and through the wood, are conducted out through similar ports. Thence the gases can be directed into the firebox of the adjoining chamber, through a water valve, or into the flue, which runs the entire length of the bottom of the kiln to the suction fan. At Domnarfvet one suction fan or exhauster produces the draft necessary. The wood is subjected to preliminary heating during six days, to drying and preliminary charring during five days, and to the final charring process during five days; while the quenching, discharging, and charging occupy four days, making a total of twenty days. In a single kiln, having eight chambers, the amount of wood contained in 146 chambers, or 891,860 cubic feet (loose measure), was charred in one year, producing 647,126 cubic feet of charcoal. The charcoal produced, as compared with the wood charred, amounts to 72·56 per cent. by volume. This includes not only the wood placed in the chambers, but also that which is consumed in the fireboxes as fuel. In meilers the yield is under 60 per cent., and all the by-products are lost.

A cubic metre of wood as charged into the kiln averages 267·54 kilogrammes of wood substance, 186·49 of water, and 1·67 of ash. The yield in kilogrammes is as follows:—

Charcoal.	Tar and Tar Oils.	Acetic Acid.	Methyl Alcohol.	Water.
111·0	3·40	6·74	2·58	304·69

besides a large volume of non-condensible gas, containing 40·34 kilogrammes of carbon.

The author also deals with the thermal equations of the opera-



various calorimeters and pyrometers, including the latest types, are fully described. Fifty pages are devoted to accounts of the various kinds of fuels, statistics of production being appended. Under the head of coal, the subject of coal-washing is gone into. It is obviously desirable that the metallurgist should not neglect this branch of the subject. The description is elucidated by drawings of the Lührig jigging machine, of the Schüchtermann and Kremer coal-washer, and of the Couffinhal patent fuel press. The bulk of the descriptive section is devoted to coke. The coke-ovens described are classified into those with intermittent working and those with continuous working (Lürmann). The latter type has fallen into disuse. The former may be with one chamber (beehive coke-ovens of various kinds) or with two. In the latter case the cooking-chamber may be vertical (Appolt, Bauer, Collin, Kleist), inclined (Dubochet), or horizontal. The ovens with horizontal chambers are further subdivided into those with vertical flues (François, Coppée, Hoffmann, Otto), and those with horizontal flues (Haldy, Knab, Carvés, Hüssener, Semet-Solvay, Festner-Hoffmann). Most of these ovens are described and illustrated. The second section of the volume deals with the manner in which heat is transmitted, with furnaces generally, and with refractory building materials.

An illustration is given * of the Chinese coke-ovens at Tong-Shan.

Coke-Ovens in Germany.—F. Simmersbach † observes that during the past eight years the production of coke in Germany has increased by more than 3½ million tons, or 55 per cent., as the following table shows:—

District.	Production in 1890.	Production in 1897.
	Metric Tons.	Metric Tons.
Ruhr	4,187,780	6,871,557
Upper Silesia	1,065,335	1,399,337
Lower Silesia	254.178	424,385
Saar	557,353	820,735
Aix-la-Chapelle	246,923	336,726
Obernkirchen	23,888	30,500
Saxony	76,063	77,500
Totals	6,411,520	9,960,740

* *Engineering*, vol. lxv. p. 585.

† *Stahl und Eisen*, vol. xviii. pp. 641–647, with illustrations and tables.

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be equal to some 19·37 per cent. of the total quantity charged into the coke-ovens.

The modern form of the Otto oven is the one that has shown the maximum annual yield—1450 tons. The author traces the variations which have taken place in the Otto oven since it was originally designed. In the most modern form the regenerator chambers are abandoned, and gas-firing under the oven is introduced in their stead. This has resulted in a considerable simplification of the oven construction. A series of large Bunsen burners are used, and the temperature above these varies between 1350° and 1400° C. This oven takes a 7-ton charge of damp coal, and yields 5 tons of coke a day, or some 1462 tons in the working year. In the old 48-hour coke-oven about 4½ tons yield was calculated for the 6-ton charge, or 900 tons a year. Comparing these ovens with those of the beehive type, the author shows how greatly they excel them as regards output. One-half the total output of coke in the Ruhr district now results from ovens provided with plant for the collection of the by-products.

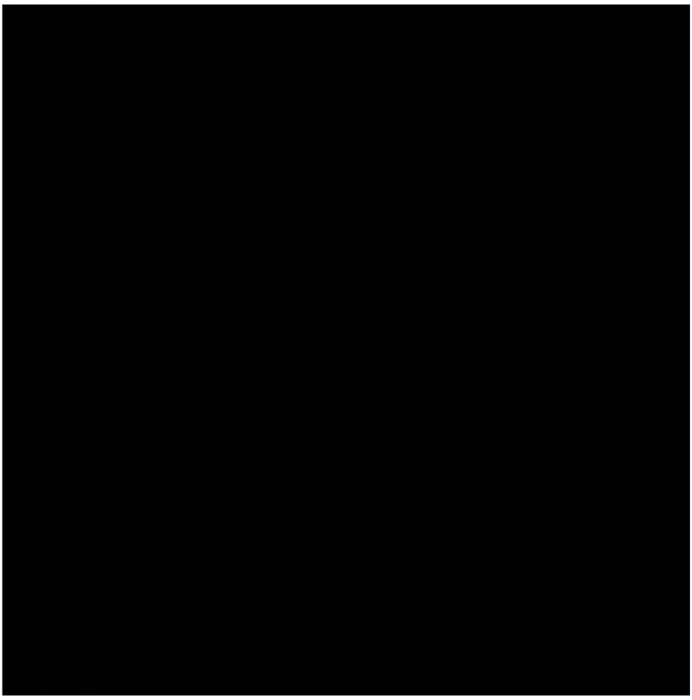
The charging of coke-ovens in Germany is done almost entirely by hand, and through three charging openings in the furnace roof. Attempts have, however, been made to replace this hand labour by mechanical appliances, and at the same time to subject the coal to compression, which the author briefly considers. He then passes to a more detailed consideration of the question of the condensation of the by-products.

Of the new form of Otto coke-oven to which the author has drawn attention, 422 were in use in 1897, and another 180 were to be in use in the present year. A battery of 50 of these ovens is also stated to have recently been put into work at Middlesbrough.

Coke-ovens and by-products in Germany are dealt with in a Foreign Office report by Kurt Seebohm. The various forms of ovens are referred to, and prices are given in some detail.

Beehive Ovens.—F. C. Keighley * discusses the most advantageous arrangements for beehive coke-oven plant. It is held that 300 ovens are the best number to be worked in one plant, and that they should be 12 feet in diameter. The situation of the plant and the arrangement of the banks are discussed, and it is recommended that they should not be built too close together, but should be separated by insulating material, not tamped in. General details are given, together

* *American Manufacturer*, vol. lxiii. pp. 481, 516, &c.



The coking coals of Western Germany contain about 1·5 per cent. of total nitrogen. Of this about 17 to 30 per cent. is volatile. The remainder, or above 1 per cent. as a rule, remains in the coke. Of the volatile nitrogen scarcely the half is collected by the forms of condensing plant now in use. The author thinks it probable that it would be possible to still further increase the percentage collected, especially by the use of very narrow coke-ovens, and short periods of coking. Coke, the author adds, which has been produced in ovens from which the by-products are collected, yields on the average about 7100 calories.

R. Terhaerst * considers the question of the by-products obtainable in the conversion of coal into coke. Amongst these is an important excess of gas over the quantity actually required for the coking process itself. Thus in the case of a coke-oven plant in Westphalia, 60 ovens yield daily an available excess of gas amounting to 847,600 cubic feet. On the assumption that 1000 cubic metres (3532 cubic feet) of gas is equal to 0·0875 ton of coal, this excess of gas is equal to a daily quantity of 21 tons of coal. The gas is used under boilers, but it may also be used for illuminating purposes. Its illuminating power may be increased by the aid of the benzol also resulting from the distillation of the coal. The author calculates that this excess gas from a battery of 60 coke-ovens would supply with gas a town having a population of 84,000. He then proceeds to deal with the question of the selection of the type of oven to be adopted. The way in which the process is carried out in the oven not only affects the character of the coke but also that of the by-products. When the distillation is rapid and the temperature high, quite different compounds form to those which are produced with slow distillation and a low temperature. The tar formed at low temperatures is, for instance, of a much lower specific gravity than that formed at high temperatures. The latter contains much benzol, toluol, and naphthalene, but the other is chiefly composed of volatile hydrocarbons. An increase of temperature in the oven is therefore an advantage in the case of those works that obtain the benzene by distillation of the tar, and not by washing the gases evolved with tar oils and then distilling these. This latter is by far the best method, and if it is to be performed, a slow distillation in the coke-oven is distinctly desirable. The author considers, however, that 48 hours should not be exceeded in the case of ovens of normal dimensions.

* *Stahl und Eisen*, vol. xviii. pp. 747–750.

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Dealing with the collection of the by-products, he states that the gases are first passed through settlers, to allow solid coal particles to separate. These are large cylinders, often provided with internal projecting plates to assist in the separation of the dust. The gases are strongly cooled in these, their temperature when leaving them being some 100° C. lower than it was when they left the coke-oven. This results in the condensation of a considerable portion of the tar. Moisture, too, condenses, and this absorbs a large portion of the ammonia in the gases. After leaving these settlers the gases pass to the water-cooled condensing plant proper. This consists of inclined boxes, usually of rectangular shape, provided both above and below with so-called false bottoms. These are connected with each other by a number of wrought-iron pipes through which water is caused to flow. In these boxes a further portion of the tar and ammonia water condenses, and their temperature is reduced from about 80° C. to about 20° C. They next pass to rectangular cast-iron boxes in which the gases are passed into water through a number of pipes. Diluted ammonia water is used for this purpose, and it gradually becomes enriched. This ammonia water is caused to flow in above as it is drawn away below, so that the gas entrance pipes are always covered to the same height by water. Behind these boxes are exhausters which force the gases forwards. By friction and compression they increase the temperature of the gases by some 8° C., and they are therefore first passed through another water-cooler, which again reduces the temperature to about 20° C. The gas is then forced into a series of bell-shaped receptacles, and brought as intimately as possible into contact with water, to collect the remaining ammonia contents. From these they pass to similar receptacles in which, however, they are washed not with water but with "tar oil" (creosote oil). This collects the benzene, which is subsequently obtained from it by fractional distillation. The gases are subsequently stored and used for heating purposes.

Tar and benzene are sold as raw products, the latter having a specific gravity of 0·87, and being from 92 to 94 per cent. pure. The ammonia water, on the other hand, is converted into ammonium sulphate. The ammonia water usually contains 1·2 per cent. NH_3. It is brought into intimate contact with steam which drives out the ammonia. This ammoniacal steam is then passed into sulphuric acid of 42° B. The ammonium sulphate crystallises out and is sold as manure, and guaranteed as a rule to contain 24·5 per cent. NH_3.

The Neinhaus oven is of the ordinary horizontal type, but to avoid

[illegible] difficulty commonly experienced in such ovens of obtaining [illegible] heat at the upper parts of the vertical channels, the [illegible] diffused from the top instead of from below. In ordinary [illegible] upper portion of the coke is of poorer quality owing to [illegible] sufficient heat, but in the Trenkner oven this practical difficulty [illegible] met. The oven is illustrated, and a modified coke-oven [illegible] described.

H. G. Hoffmann* describes the application of by-product ove[illegible] generating illuminating gas for the use of towns, and at the same [illegible] supplying coke suitable for blast-furnace use. At [illegible] modified from [illegible] to the [illegible] type are [illegible] with Otto-Hoffmann ovens are to be [illegible] coal [illegible] same purpose. Full results are given of the by-products produ[illegible]

Dr. C. [illegible] † gives a further description of the Otto co[illegible] and by-product recovery plant, with particulars of its working.

W. B. Phillips ‡ gives the result of a test made with about [illegible] of slack coal from Jefferson County, Alabama, in the Otto-H[illegible] ovens at Glassport, Pennsylvania. The coal contained—

Moisture	Volatile Matter	Fixed Carbon	Ash	Sulphur	Pho[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

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coke is usually produced in 24 hours, but might be made in 20. These ovens work hotter than the others. In the case of the vertical ovens the coking process lasts from 24 to 48 hours. These two types of oven, while differing in important matters from other types of coke-oven, yet differ among themselves only in the construction of the side channels. The oven is so arranged that the by-products may either be collected or not collected as may be desired, and burners are also placed in the oven with a view to produce a homogeneous product. The author first describes the oven with vertical side channels by the aid of illustrations, and then passes to a description of the oven with horizontal channels. In the ovens with vertical gas channels the coke is produced at the rate of about 3 tons in the 24 hours' firing. In the case of a battery of 50 horizontal gas-channeled ovens the year's balance-sheet is about as follows in the case of a German plant:—

Coal coked		100,000 tons.
Products:—	Tons.	Value, Florins.
Ammonium sulphate	1,200	122,400
Tar	3,300	39,600
Benzene	550	158,400
Coke	77,000	739,200

The total value of the products thus amounts to 1,059,600 florins, or £88,300. The cost of production, on the other hand, amounts to 473,179 florins, or £39,432:—

	Tons.	Value, Florins.
Coal	110,000	330,000
Sulphuric acid	1,000	21,600
Oil for benzene absorption	48	2,419
Steam and water	......	7,200
Lubricators	......	1,200
Wages, taxes, &c.	......	72,000
Repairs	......	1,200

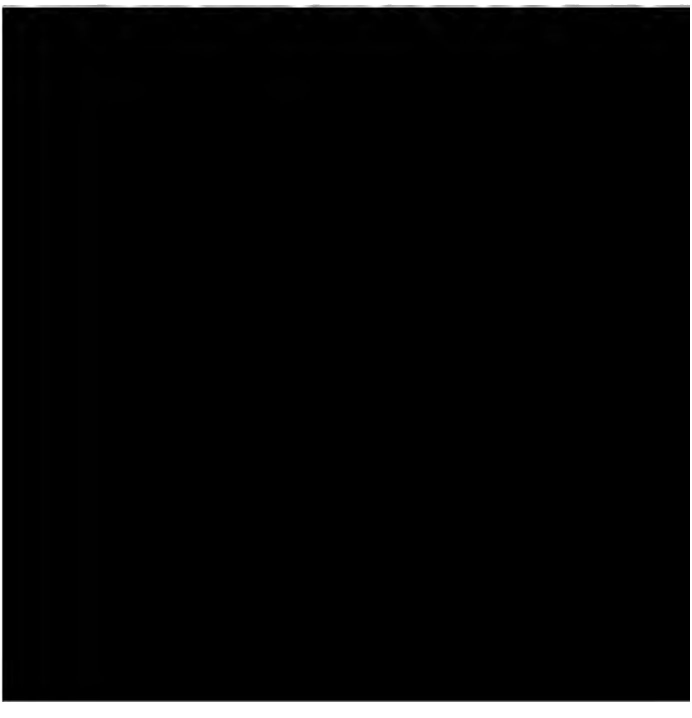
In the case of the Victor works at Rauxel, in Westphalia, the following results were obtained. The coal coked contained—

Carbon.	Ash.	Moisture.
80·13	6·04	10·10

and the coke produced—

Ash.	Moisture.
7·45	2·5 to 3·0

It was hard, compact, and silver grey in colour. The charge coked weighed from 6·23 to 6·6 tons, and this was coked in 33 hours with a yield of 79·5 per cent. The tar collected amounted to 1·65 per cent.,



G. T. Holloway * gives an account of the petroleum industry, describing generally the occurrence, composition, production, and treatment of the oil in America and Russia.

Petroleum in Galicia.—An exhaustive memoir on the oil industry of Galicia has been published.† The latest statistics show that there were 706 oil shafts and 1895 boreholes. The oil is raised by 200 hand-pumps and 117 steam-pumps. For fuel Silesian coal is used, and here and there natural gas. The deepest borehole is 2310 feet. The Canadian system of boring is that usually employed.

H. Arch ‡ describes the occurrences of ozokerite in Galicia.

Petroleum in Croatia.—C. von John § has analysed crude petroleum from a trial shaft 10 yards deep at Lepavina, Croatia. The oil is of a greenish black colour, and has a specific gravity of 0·845. Submitted to dry distillation, there was obtained—

	Per Cent.	Specific Gravity.
Benzol at 100° C.	2·45	0·770
Light oils at 100°-150°	7·93	0·790
Illuminating oils at 150°-200°	10·35	0·817
Illuminating oils at 200°-250°	10·76	0·830
Illuminating oils at 250°-300°	28·33	0·851
Heavy oils above 300°	33·35	0·867
Petroleum rubber	1·85	...
Coke residue	3·80	...
Gases and loss	1·18	...
Total	100·00	...

The illuminating oils amounted to 49·44 per cent.

Petroleum in Hungary.—C. von John ‖ has analysed crude petroleum from a borehole at Körös-Mező, Hungary. The oil is of a dark brown colour, and has a specific gravity of 0·785. On dry distillation it yielded—

	Per Cent.	Specific Gravity.
Benzol at 100° C.	13·85	0·717
Light oils at 100°-150°	20·90	0·743
Illuminating oils at 150°-200°	12·85	0·765
Illuminating oils at 200°-250°	13·54	0·783
Illuminating oils at 250°-300°	22·31	0·824
Heavy oils at 300°-350°	6·13	0·856
Heavy oils rich in paraffin above 350°	8·00	0·862
Petroleum rubber	0·05	...
Coke	0·87	...
Gases and loss	1·50	...

* *Knowledge*, vol. xxi. pp. 125, 151, 169.
† *Chemiker Zeitung*, vol. xxii. pp. 512-513.
‡ *Allgemeine Oesterreichische Chemiker- und Techniker Zeitung*, 1898, p. 5.
§ *Jahrbuch der k.k. geologischen Reichsanstalt*, vol. xlvii. p. 763.
‖ *Ibid.*, vol. xlvii. p. 764.

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accurately fix the position of a subterranean reservoir of petroleum. The strike of the oil-bearing strata is irregular, and the dip variable, while intervals exist where the sand is barren of oil. In many cases the accumulation of bitumen has been caused by the bitumen draining from higher to lower levels.

Petroleum in Indiana.—W. S. Blatchley,* State Geologist of Indiana, has issued his report (occupying 1197 pages) on the work accomplished by the department of geology and natural resources during the year 1897. A large proportion of the energies of the department were employed during that year in collecting data for a detailed report on the coal area of the State, shortly to be published. The present report includes papers of economic importance relating to petroleum, stone and clay resources of the State, the reports of the chiefs of the divisions pertaining to mines, natural gas, and illuminating oils.

Petroleum in Ohio.—An important discovery of petroleum is announced.† At New Waterford, Ohio, two prolific wells have been found. New Waterford is 56 miles from Pittsburg.

Petroleum in Texas.—T. D. Miller ‡ describes the recently developed oil-field of Texas, at Corsicana. Oil was here struck in 1894 at a depth of 1027 feet. Other wells encountered the oil stratum at about the same depth. The layer seems to dip to the south-east about 1 in 100. At the present time there are about a hundred producing wells. The yield in the wells is intermittent, and appears to have a regular diurnal variation. The oil is dark brown and opaque; it has a specific gravity of 0·8292 at 60° F. The results of fractional distillation are given.

Petroleum in Persia.—According to R. Helmhacker § petroleum is found in the tertiary deposits on the south-west border of the Persian highlands. It is apparently abundant in the section bordering on the Persian Gulf. Along the Gulf shore there are oil springs which were known at a very early date, and were described by Strabo in the econd century. Oil springs are also found in the Bakhari Range in

* *Nature*, vol. lviii. p. 629.
† *Age of Steel*, vol. lxxxiv., No 1, p. 18.
‡ *Engineering and Mining Journal*, vol. lxv. pp. 734–735.
§ *Ibid.*, vol. lxvi. p. 39.

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seams from 1 to 2 feet in thickness, which is termed "manjak." It possesses a black lustrous appearance, and is found at shallow depths or even at the surface. It is thought to be a kind of solidified petroleum, as the latter frequently occurs with it. The better varieties of this mineral contain—

Fixed Carbon.	Volatile Matter.	Water.	Ash.
26·97	70·85	2·00	0·18

It therefore is much more bituminous than the Trinidad mineral, which contains from 21 to 30 per cent. of water and 38 per cent. of ash. It possesses strong insulating properties, and might perhaps replace gutta-percha in electric work.*

Petroleum Vapour Burners.—J. S. V. Bickford † gives the results of his experiments on the use and production of petroleum vapour, and describes various forms of plain jets, blowpipe and Bunsen burners, with the difficulties that occur in getting the vapour to burn.

Origin of Petroleum.—S. F. Emmons ‡ considers that the geological structure of the petroleum deposits at Baku and the conditions of flow seem to fit the anticlinal theory expounded for the American oil-fields by Professor Orton. In reference to the origin of the petroleum, he points out that the Caspian Sea is extremely rich in fish. Shoals make their way into the Karabagas Gulf, and as the strong salt solution acts on them as a poison, they die and are washed out on the shores in immense numbers. Birds eat out the eyes and entrails, but do not touch the flesh, which, being thoroughly salted, is preserved from decay, and serves as food for the neighbouring Turkoman tribes. It is easy to conceive how such masses of organic matter, buried by sand and mud, and finally forming part of a sedimentary formation, might, after the necessary chemical changes had taken place, form an important source of petroleum.

O. Lang § discusses the origin and chemical constitution of petroleum, with special reference to the theories propounded in America by S. P. Sadtler, by S. F. Peckham, by D. T. Day, by F. C. Phillips, and by C. F. Maybery.

* *Génie Civil*, vol. xxxii. p. 370; *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvi. p. 413.

† *Engineer*, vol. lxxxvi. pp. 49–50.

‡ *Transactions of the American Institute of Mining Engineers*, 1898 (advance proof).

§ *Glückauf*, vol. xxxiv. pp. 533–535.

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J. T. Hewitt * also describes the occurrence of natural gas at Heathfield station. Owing to the courtesy of R. J. Billinton, locomotive superintendent of the London, Brighton, and South Coast Railway, he was enabled to take a sample of the gas, which he analysed with the following results :—

	Per Cent.
Marsh gas	91·9
Hydrogen	7·2
Nitrogen	0·9

Oxygen, carbonic anhydride, carbonic oxide, olefines, and hydrocarbon vapours were found to be absent. The author also analysed a specimen of the shale encountered at a depth of 300 feet.

Use of Natural Gas.—J. J. Flather † describes a plant recently installed in Lafayette, Indiana, in which natural gas is used in gas-engines for driving dynamos for light and power purposes. Two 125 horse-power engines, driving two 60-kilowatt two-phase generators, are running, and a third is to be built.

VII.—*ARTIFICIAL GAS.*

Gas-Producers.—A. Sailler, ‡ in discussing gas-producers, observes that blast-furnaces, coke-ovens, &c., are also gas-producers, but with them he does not deal. The chief objection to direct-firing on grates lies in the excess of air employed, the loss in cinder formed, and the impossibility of attaining in this way, especially with poor fuels, the high temperatures required for many metallurgical processes. To avoid these difficulties gas-firing has replaced the older method in many instances; but in so replacing it many of the advantages of the older method were lost, and it is the aim of modern improvements in producer designs to regain these advantages of the direct-firing process and yet avoid its disadvantages. The older forms of producer were by no means satisfactory. The use of compressed air below the fire-bars was gradually introduced, and an important step in advance was made in Austria in 1878 by the introduction of high producer shafts and high pressure blast below the grate. Before the intro-

* *Quarterly Journal of the Geological Society*, vol. liv. pp. 572–574.
† *American Electrician*, June 1898.
‡ *Zeitschrift des Oesterreichischen Ingenieur- und Architekten-Vereines*, vol. l. pp. 385–386.

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substance, and if placed in an apparatus so arranged that a large surface of the gasolene is exposed to the action of a current of air, this latter becomes saturated with gasolene, and "air-gas" is the result. This is a powerful illuminant. The author describes and illustrates one such apparatus. He then proceeds to consider the character of the gas produced, and gives comparative experimental results to show its properties. A mixture of gasolene vapours and air is only of an explosive character when the two are present within certain definite ratios, but these proportions are never found in air-gas produced in the ordinary way. These limits closely approach those that exist in the case of ordinary coal-gas and air mixtures. Gasolene air-gas contains no carbon monoxide, carbon dioxide, or ammonia, except such as were present in the air used, and sulphur only occurs in traces. Consequently the gas does not damage pictures, &c. The use of this gas for laboratory purposes is specially referred to by the author, both as an illuminant and as a source of heat. He used it with much success for fusion purposes in assay crucibles.

VIII.—*COAL-MINING.*

Deep Boring.—F. H. Davis * describes the Davis-Calyx drill, of which the special points are the form of the teeth in the steel-cutter crown and the sediment tube on the rods.

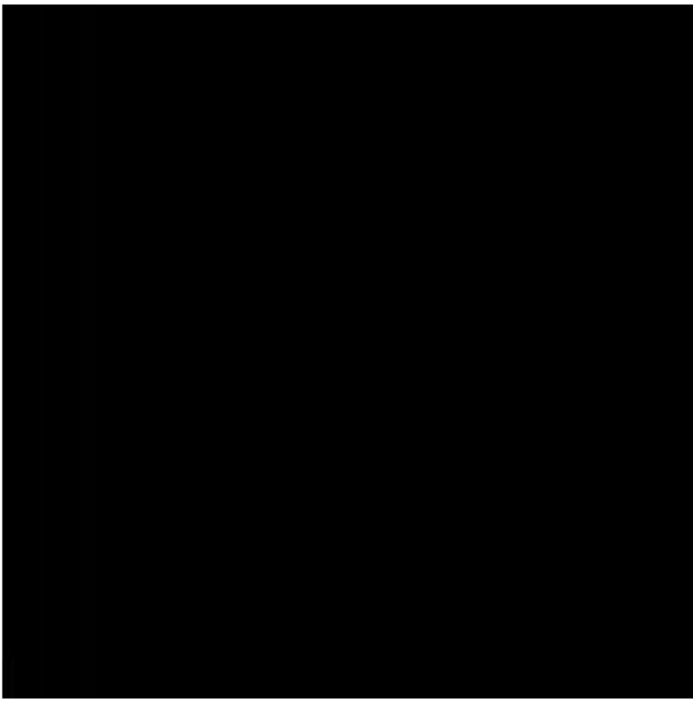
A description is published † of the removal of broken portions of a drill from a borehole about 930 feet in depth, near Ostroppa, in the Gleiwitz district of Austria-Hungary. A variety of unsuccessful efforts had been made to withdraw the broken fragments, but success at last resulted when an electro bar magnet was improvised, lowered into the borehole, and the fragments removed by its aid in a single day; whereas the previous efforts had been continued for three weeks before being abandoned. The magnet had a lifting power of about 1 cwt.

A. Fauck ‡ describes a percussion drill which enables cores to be obtained in the same way as when a diamond drill is used.

* *Transactions of the Institution of Mining Engineers*, vol. xv. pp. 363–377.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvi. p. 250.

‡ Paper read before the Austrian Association of Engineers and Architects; *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvi.; *Vereins-Mittheilungen*, pp. 44–45, with three illustrations.



W. D. Wight * gives the following particulars of rapid work in winding coal. The colliery in South Wales which raised the largest quantity of coal in one year from one shaft with one engine was the Albion Colliery, with 551,000 tons. The Silksworth Colliery, county Durham, raised in its best year 535,000 tons from about 580 yards, with two engines winding out of the same shaft, but the Albion beat that record with a single engine. Last year, at the Bolsover Colliery in Derbyshire, 598,798 tons of coal were raised in 279 working days from a pit 365 yards deep. This beats anything in South Wales, but at Denaby Main Colliery there were no fewer than 629,947 tons of coal raised in 281 working days last year, the largest quantity per day being 2673 tons. As collieries get deeper the difficulties increase, and in the future recourse must be had to other methods of raising coal; a system of endless winding at slow speed may be adopted. In Lancashire four collieries have been fitted on this principle. An estimate is then given for a colliery 600 yards deep raising 200 trams hourly, at a rope speed of 3 feet per second.

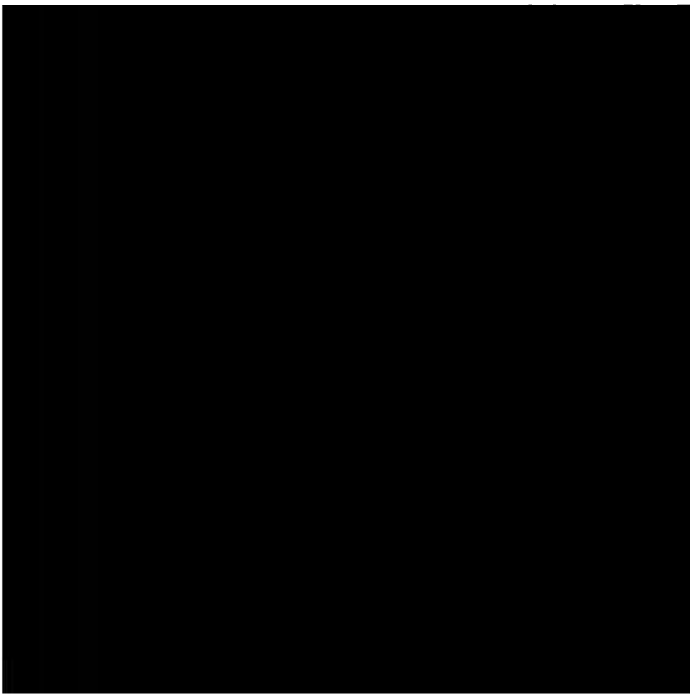
E. Tomson † describes the pit-head pulleys adopted at the Preussen No. 2 Shaft of the Harpen Colliery Company, near Dortmund. These pulleys are of the Bascoup type, and have eighteen arms supporting a wrought iron rim. Four of these pulleys are arranged in the head-gear with their bearings out of line, as they are only 3 feet apart.

W. Saint ‡ describes a new device that has been designed for use in mid-shaft when it is necessary to use a cage balance for decking purposes, so that the passage of air is not impeded. It was devised by J. Tinsley, of Ashton Moss Colliery, where the invention has worked very satisfactorily. It consists of two carriage frames lying horizontally within the pit shaft, for receiving the descending cage loaded with men, empty corves, &c., and the machinery requisite for operating them. The frames are arranged so that when one is lowered for decking purposes the other ascends in readiness to do similar work.

Illustrations have appeared § of a self-emptying cage with a tipping hopper bottom, large enough to hold two tubs of coal.

Experiments have recently been made by Schale ‖ at several Prussian collieries with speaking-tubes for signalling purposes.

* *Proceedings of the South Wales Institute of Engineers*, vol. xxi. pp. 23–28.
† *Revue Universelle des Mines*, vol. xli. pp. 137–220, 237–287.
‡ *Transactions of the Manchester Geological Society*, vol. xxv. pp. 577–580.
§ *Iron and Coal Trades Review*, vol. lvi. p. 524.
‖ *Zeitschrift für Berg- Hütten- und Salinenwesen im preussischen Staate*, vol. xlv. pp. 271–276.



position are given, and also the temperature of the rock and the daily variations in the Bendigo mines.

Underground Haulage.—Plans and elevations of some large hauling engines erected at two Welsh collieries have recently been published.* The cylinders are 22 inches in diameter, and have a 3 feet 6 inch stroke. The valve mechanism is the simple slide valve. The spur gearing is made of toughened cast steel, in halves, and is fitted together, bored, and keyed with two steel keys on the shaft. The teeth are double helical, with a ratio of wheels of 2½ to 1. The drum shaft is steel, 12 inches diameter, and carries two drums 6 feet diameter by 3 feet wide between flanges, and 15 inches deep. The clutches are of cast steel. The piston-rods, cross-head cap and gudgeon, connecting-rods, link motion eccentric rods, and crank-pins are of forged steel. The crank-shaft is steel, 9 inches diameter in the body and 9½ inches in the pinion. The guide bars are cast iron; the bottom guide bar is made channel-shaped to retain the oil. The bed-plate is made of steel in box form, is 12⅝ inches deep by 11 inches wide at top in two lengths. The front cross-girder is of box form, 12⅝ inches deep by 13 inches wide, and carries the front end of the engine-bed, enabling the ropes to work underneath. The specification for the drums is also given. The engines are placed on the surface and the ropes carried down the shaft.

The endless-rope haulage installation at the Monceau-Fontaine collieries is described.† The rope is carried over the tubs, and is gripped by forks on them. Sheaves are provided with star-like flanges to allow the forks to pass.

Illustrations have appeared ‡ of an endless-rope haulage plant at the Grimberg pit of the Monopol mines, near Camen, Germany. The engines and plant generally are described.

C. W. Westgarth § deals generally with the subject of haulage, giving special attention to the various systems of endless-rope haulage.

T. E. Forster ‖ and F. R. Simpson give some details as to the cost of secondary haulage by ponies in the north of England.

At the Segen-Gottes shaft of the von Burgker works in Saxony an endless rope has replaced the horse haulage underground that was

* *Iron and Coal Trades Review*, vol. lvi. pp. 514–515.
† *Annales des Mines de Belgique*, vol. iii. No. 3.
‡ *Glückauf*, vol. xxxiv. pp. 640–641.
§ Paper read before the British Society of Mining Students.
‖ *Transactions of the Institution of Mining Engineers*, vol. xv. pp. 136–141.

has been used in Neunkirchen, Silesia, and Westphalia with very satisfactory results.*

Exhaustive experiments have been carried out † at the testing gallery at Gelsenkirchen, under the charge of Heise, on the possible dangers due to the use of electric appliances in fiery and dusty mines. The general conclusions of the report are that electric apparatus is safe when ordinary precautions are employed in the mine. Many tests were made with incandescent lamps, which sometimes caused an explosion and sometimes did not. Apparently a current not exceeding 0·6 ampere and 150 volts is safe. Switches, cut-outs, resistances, fuses, commutators, &c., were also tested, and the results are given.

Mine Timber.—H. Louis ‡ has made a series of experiments on the strength of pit-props, and gives the results in tabular form. The main conclusions drawn are as follows:—Of the soft woods generally used, Baltic white wood, red wood, and larch are strongest, having a strength equal to 1½ ton per square inch of area of the small end. Strength is independent of length within ordinary limits. Slow-grown timber is somewhat preferable. All timber should be seasoned. Only seasoned timber should be treated, and should be seasoned again before use. Crooked props, props with big knots, and, above all, gouge-marked props should be avoided; wind shakes are of less importance. A prop that has been drawn is decidedly weaker than when originally set.

H. W. F. Kayser§ discusses the use and preservation of mining timber, and advocates the use of means for preventing its decay and for fireproofing it.

A recently published pamphlet on the mining resources of Calaveras County gives some tests and particulars of timber grown for mining purposes in that district.‖

According to C. Dütting,¶ pines and firs have been used of late with success in the mines of the Saar district, and it is found that these stand the mine atmosphere better than ordinary woods of other kinds. The oak has been much overvalued, and indeed it has proved the least satisfactory of all woods tried.

* *Mining Journal*, vol. lxviii. p. 1166.
† *Glückauf*, vol. xxxiv. pp. 370–373.
‡ *Transactions of the Institution of Mining Engineers*, vol. xv. pp. 343–362.
§ *Transactions of the Australasian Institute of Mining Engineers*, vol. v. pp. 3–7.
‖ *Engineering and Mining Journal*, vol. lxv. pp. 430–431.
¶ *Glückauf*, vol. xxxiv. pp. 797–803.

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machines. In 1897 they were in use in twenty States, and the number of machines has increased to 1988 as compared with 1446 in 1896. The coal mined with their aid has increased from about 16½ to over 22½ million tons, or from 12·56 to 16·17 per cent. of the total output of coal.

V. Waltl* observes that it was some fifty years ago when the introduction of machine-getters in the collieries of the United Kingdom led to a marked change in coal-mining. About twenty-five years since there was a good deal of correspondence in the technical journals with reference to these appliances, the earlier types of which he names and describes. Compressed air was the motive-power nearly always employed, though hydraulic power has also been adopted; and of late, of course, electric power has been very widely introduced. Coal-getting machines he divides into four main types. Each of these classes the author deals with in detail, mentioning the various known forms of such appliances under their respective headings, and describing the results that have been obtained in practice. A very large number of such appliances are referred to, and many of these are dealt with in considerable detail.

Explosives and Blasting.—W. Maurice,† in the third part of his paper on electric blasting, discusses various forms of gas cartridges and heat absorption devices. Under the former heading are included various fanciful devices such as water decomposed in a closed casing, nitrogen chloride generators, and so forth. The second heading includes various forms of safety cartridges such as those of Settle and others.

W. Cullen ‡ describes the explosive Kynite, which is composed of a mixture of nitro-glycerine, barium nitrate, wood meal, and sodium carbonate.

H. Schaw § thinks that high-pressure steam might be used instead of explosives in fiery coal-mines, and suggests that a cartridge of water placed in a shot-hole should be converted into steam at a pressure of about 150 lbs. per square inch by means of electricity of low tension, the cartridge or boiler to be made of such strength that it would burst at about this pressure, when the force set at liberty would break down the coal. It is calculated that a cartridge 1¾ inch in diameter and

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvi. pp. 284–286, 303–307, and 315–319.

† *Transactions of the Institution of Mining Engineers*, vol. xv. pp. 189–202.

‡ *Ibid.*, vol. xv. pp. 181–186.

§ *Ibid.*, September 1898 (advance proof).

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Arthur Kirk * has published a brief history of the advance and use of explosives.

L. Holan † states that another new explosive is that termed "Promethee." It consists of two materials, one solid and one liquid. The solid used possesses one or other of the following compositions:—

	I.	II.	III.
Potassium chlorate	56	76	80
Manganese peroxide	20	...	20
Ferric oxide	24	24	...

These substances are finely powdered, and then placed in cartridge cases made of porous paper, which are intended to facilitate the absorption of the second or liquid constituent. The composition of this latter is given as follows, an aromatic oil sometimes replacing the oil of bitter almonds:—

	I.	II.	III.	IV.	V.	VI.
Petroleum	50	50	50	80	100	...
Turpentine	40	30	50	15	...	100
Oil of bitter almonds	10	20	...	5	...	...

This liquid constituent is kept in closed half-litre metallic bottles until immediately before use, and is not added to the solid cartridge until immediately prior to blasting. The cartridge then consists of three parts solid and one part liquid. Up to the time when they are dipped into the liquid the solid cartridges cannot be exploded or lit, and do not suffer from damp or frost. The oil, too, is not very readily lit, and when set fire to burns steadily with a quiet smoky flame. Both constituents when separate are, therefore, safe and easily transportable. When, however, the oil has been absorbed by the solid cartridges, a process which requires 10 or 15 minutes to complete, they become high explosives. An explosion results when they are struck between two steel plates, or when a cap is used, but not otherwise. Thus they burn steadily without explosion when lit, and do not explode when in the vicinity of other cartridges that are exploding. This somewhat

* *Proceedings of the Engineers' Society of Western Pennsylvania*, vol. xiv. pp. 64-77.

† *Revue Technique; Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvi. pp. 453-454.

During recent years the use of explosives, in such cases, has considerably increased, and experience shows that the safest explosives used are the following:—

In France, the Servan-Livry explosive, grisoutine, and specially grisounite.

In Germany, roburite, the new westphalite, and carbonite.

In England, roburite, ammonite, and bellite.

In Austria, safety dynamite, and

In Belgium, Favier powder and grisoutite.

Working Coal.—With the aid of illustrations R. Mellin * describes the board and pillar method of mining as used at Tudhoe colliery, Croxdale, at Usworth colliery, Newcastle, at Whitehill and Greenfield collieries, Scotland, and at Silverdale colliery, North Staffordshire; the long wall system as used at Cannock and Rugeley collieries, South Staffordshire, at Albion colliery, South Wales, at Leven colliery, Scotland, at Witley colliery, Birmingham, at Great Fenton colliery, Stoke-on-Trent, at Nunnery colliery, Sheffield, and at Whitefield colliery, Tunstall; the combined board and pillar and long wall method at Llanbradach colliery, South Wales, and at Nunnery colliery, Sheffield; and lastly, other methods of mining used at Hamstead colliery, Birmingham, and at Niddrie colliery, Edinburgh.

H. Pasquet describes † the working of thick seams of coal. The memoir is practically a general study of coal-mining in the Loire coal-field. The beds of coal are classed according to their thickness as (1) thick beds of 6 yards and above; (2) average beds of 3 to 6 yards; and (3) thin beds of 3 yards to 4 feet. In each case details are given of the nature of the bed, of the method of working, and of improvements that might be introduced. Numerous plans and dimensioned drawings are appended.

J. T. Beard ‡ shows how small coal-mines may be economically worked where the seams are thin and shallow, and the field limited.

J. Cain § describes the methods of working at the Thomas mines, Whitwell, Tennessee.

Full details are given of the amount of work done by colliers in the different seams of the Rossitz collieries.||

* *Zeitschrift für das Berg- Hütten- und Salinenwesen im preussischen Staate*, vol. xlvi. pp. 158–184.

† *Bulletin de la Société de l'Industrie Minérale*, vol. xii. pp. 5–106.

‡ *Mines and Minerals*, vol. xix. pp. 1–4. § *Ibid.*, pp. 57–59.

|| *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvi. p. 233.

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that the pits of the Martel collieries, with five winding plants, employ six hundred ratchet drills in ordinary work. One of the chief difficulties in the way of coal-mining in Northern France lies in the absence of suitable mine timber. Iron props are consequently being used instead. The conditions existing in the United Kingdom are, the author states, in many respects different from those that exist on the Continent. The collieries are the most important in the whole of Europe. The conditions of working, too, are most favourable, and the seams are not only rich, but shipping facilities are very readily available. As a rule, he observes, two seams are worked at a colliery, to work three seams being rare, and each shaft, too, winds from a single seam. Mine timber is even more wanting than in the North of France, and has to be imported largely from the South of France and Norway. The seams as a rule are more or less horizontal. The absence of suitable timber props has here again led to the use of iron props on a large scale. To suitable and adequate water communication the success of coal-mining in the United Kingdom is to a very considerable extent due. England, the author says, has three chief coal districts: (1) That of Newcastle; (2) the central coal basin; and (3) that of South Wales. These he deals with in more or less detail, together with the methods of mining that are in use, and the labour conditions. The author subsequently in conclusion compares the conditions existing in Austria, and especially in the Ostrau-Karwin district, with those existing elsewhere.

Coal-Mining in Bavaria.—Among the papers read at the recent Mining Congress in Munich was an interesting memoir on coal-mining in Upper Bavaria, by L. Hertle,* managing director of the Upper Bavarian Coal Company at Miesbach. The coal occurs in numerous thin seams at the northern edge of the Bavarian limestone Alps, and is of Oligocene age. Between Inn and Lech, for a distance of 60 miles, with a mean width of 3 miles, the seams are workable, the thickness being at least 20 inches. Mining operations are carried on at Miesbach, Hausham, and Pensberg, by the Upper Bavarian Company, and at Peissenberg by the Bavarian Government. Fortunately little difficulty is presented in mining owing to the absence of water and quicksand in shaft sinking. There is also no fire-damp worth speaking of, and no dangerous coal dust. Underground haulage is effected by horses, but rope haulage will shortly be installed. The winding-shafts are

* *Glückauf*, vol. xxxiv. pp. 853–864.

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Coal-Mining in Canada.—An account of a visit to the collieries at Nanaimo, Vancouver, has appeared in pamphlet form, and contains a general account of the mines and plant.*

Some illustrations of the surface-works at Springhill Colliery, Nova Scotia, have appeared,† together with a short description of the plant and workings.

Mine-Pumps.—A lengthy paper on the Kley pumping-engine at the Franz shaft of the Idria mines has been published by Carl Habermann.‡ In selecting the engine care had to be taken that it should not be too costly, that it should work very economically, owing to the high price of fuel at Idria, and that it should permit of considerable variation in the number of strokes per minute. A Woolf engine, modified by Kley, was eventually chosen, and was found to work perfectly satisfactorily. The consumption of steam has been lower than that reached by any other type of surface-pumping plant. The average annual working cost per effective horse-power per hour is 1¼d. The total cost of the plant was as follows:—

	£
Engine-house	482
Foundations	629
Engine with crane and spare piston	4,694
Rods and pumps	3,371
Boiler-house	609
Boiler masonry	284
Boilers	507
Stack	250
Miscellaneous operations	410
Total	11,236

At the present time about 50 Kley pumping-engines are at work on the Continent.

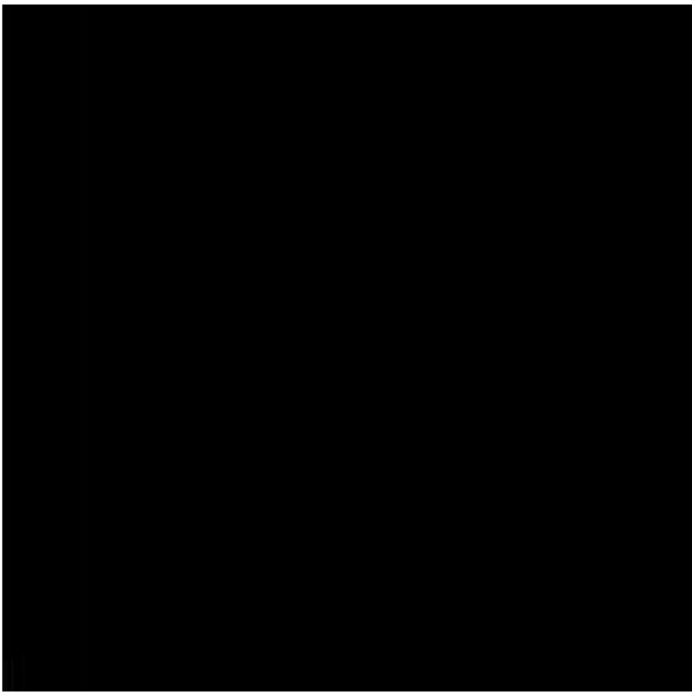
A full-page plate has been published § of the triple-expansion mine pumping-engine built at the Worthington Works for the North Hill Mine, New Jersey. The machine shows some novel features that are especially desirable for underground installations where it is necessary to have every part of the engine as accessible as possible. The piston-rods are so arranged that the high and intermediate steam cylinder heads may be taken off and the pistons taken out without disturbing

* *The Coal Industry of Vancouver Island*, p. 26, Victoria, B.C.

† *Iron and Coal Trades Review*, vol. lvii. pp. 51-52.

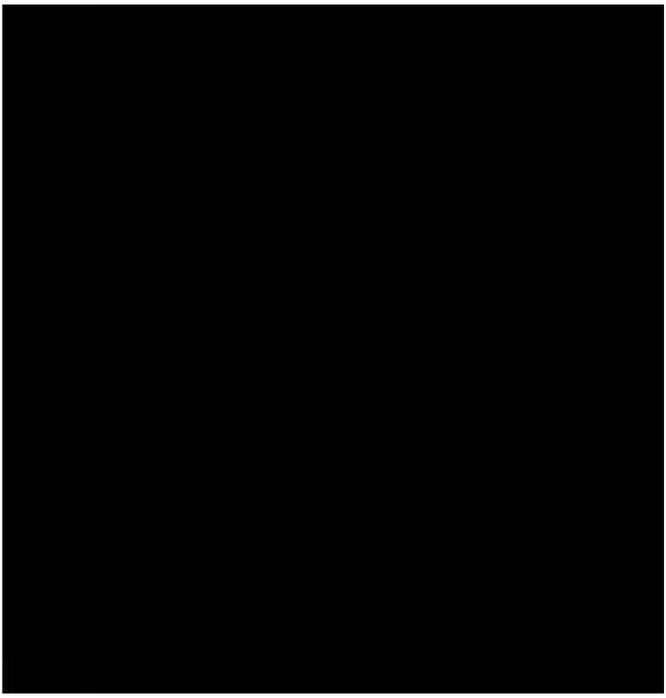
‡ *Zeitschrift des Oesterreichischen Ingenieur- und Architekten-Vereines*, vol. l. pp. 545-549, 557-562, and 572-579.

§ *Engineering News*, vol. xxxix. p. 285.



of water to be dealt with has been reduced from 36,000,000 gallons to 9,000,000 gallons daily, but an endeavour is being made to reduce this to 6,000,000 gallons.

In 1895 a combined scheme for draining the mines and the surface was brought out. It proposed the establishment of two main pumping and hydraulic-power producing plants, underground levels, and a hydraulic-power distribution main, which power was not only to be used for working semi-portable deep pumps, but also to be made available for the actuating of surface-pumps situated in the low-lying areas. A large proportion of that part of the scheme which referred to the driving of the underground levels has been carried out. The commissioners were faced with the difficulty of either having to make an underground level from the pumps to every colliery in the district which was required to be worked, or to revert to the original state of affairs of having a pumping-station in almost every colliery. This was altogether a position which it was impossible to contemplate either from an engineering or financial standpoint. Twenty-two tons of water were pumped in 1873 to 1 ton of coal or other mineral; and in 1898, notwithstanding the great reduction in the water, the commissioners' engines were pumping 24 tons of water to 1 of mineral, while, if the water raised by pumping-engines were added, the proportion was 28½ tons. The only way to bring down the cost of working an increased number of stations within the range of the revenue was, by some means not before available, to diminish the quantity of water that daily found its way to the mines from the surface. Having secured, through the Midland Electric Corporation for Power Distribution, the prospect of an early supply of electric energy at a cheap rate, the scheme for the extended drainage of the low-lying portion of the surface became feasible. All the area of the Tipton district had been re-examined for suitable places for surface-pumps, and fifty sites had been selected and surveys made for delivery channels to convey the water pumped to some existing watercourse. The quantity of surface-water to be diverted from the mines was 3,000,000 gallons per day on the average, and this will probably be dealt with by centrifugal pumps, as it will only have to be lifted 10 to 20 feet. Where there were at present steam-pumps, pumps worked by electricity would be substituted, and in consequence each place would produce greater effects than with the present steam-pumps, as the electric pumps would be automatic, and might all be set to work simultaneously after a storm, instead of waiting, as with the steam-pumps,



Fire-Damp Detection.—Papers on the analysis of the air of mines, &c., were read by O. Bleier and by R. Jeller at the International Chemical Congress. The latter has elsewhere * described the different apparatus, especially those of Coquillion's type.

Colliery Explosions.—H. Couriot and J. Meunier † describe their investigations on the explosion of mixtures of fire-damp and air by electric currents.

D. Griffiths ‡ describes a peculiar explosion of coal-dust at the Crested Butte Mine, Colorado.

An article on methods of dealing with coal-dust has recently appeared.§ The means for preventing its formation are enumerated. They consist of soaking the coal *in situ* by forcing water into boreholes, application of water during undercutting, wetting the coal after it is broken down or when it is loaded into the tubs, precautions in handling and hauling the coal, and wetting it again if necessary at the surface when it is being emptied by the tipplers on to the screens. The various systems of pipes and water-carts are described, and their relative merits discussed. Reference is also made to the use of salt, salt-water, and clay in laying dust. The removal of the dust by water-carriage in the ditches, or by tubs, is then considered, and finally several methods of obviating the deposition of fine dust are dealt with, these including the preparation of smooth and uniform surfaces such as brickwork, plaster, or corrugated iron in place of timber or steel girders which afford so many lodgments for the dust.

Respiration Apparatus.—J. Mayer ‖ describes the Neupert-Pilar respiration apparatus for exploration work in bad air. Its total weight, including mask, oxygen bottle, and absorption device is 15½ lbs.

L. Denoël ¶ discusses the employment of life-saving appliances. Although there has long existed a very great number of appliances enabling a man to penetrate into dangerous atmospheres, up to quite recently none of these inventions had come into general use in mines.

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvi. pp. 351–354, 369–372, and 389–392.

† *Revue Universelle des Mines*, vol. xliii. pp. 93–102; *Comptes Rendus de l'Académie des Sciences*, vol. cxxvi. pp. 901–904.

‡ *Mines and Minerals*, vol. xviii. p. 496.

§ *Colliery Guardian*, vol. lxxvi. pp. 737–738.

‖ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvi. pp. 1–4, 17–22, and 34–38.

¶ *Annales des Mines de Belgique*, vol. iii. part 2. Brussels: Polleunis et Ceuterick, 1898.

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made that coal was first discovered on the Continent at Liége in the year 1198. The object of F. Büttgenbach's pamphlet * is to prove beyond doubt that this assumption is erroneous, coal having been used as far back as 1113, or eighty-five years earlier, at Kirchrath on the Wurm, where it has been mined without interruption ever since. The author, a mining engineer, whose writings are much appreciated on the Continent, bases his statements on the archives of the Klosterrath Abbey, which date from 1104 to 1793. His account of the gradual development of the mining industry of the district is full of interest. With the slight knowledge of geology in vogue at that early date, it is astonishing how much underground work was carried out by the Klosterrath monks. In the troubled times of the French Revolution the Abbey was closed, and in 1797 its property was publicly sold, the mines passing into the hands of private individuals and companies. At the present time the mines on the German side are in the hands of the Wurm District Consolidated Colliery Company, who also own several productive mines in Dutch territory.

T. E. Lones † has written a short history of mining in the Black Country, in which the coal and iron trades of South Staffordshire are reviewed from the earliest period up to the present date. The work is chiefly devoted to coal-mining and the advances in the appliances used, the increase in the number and area of seams worked, and the effect of the various Royal Commissions are treated.

An interesting history has been published ‡ of the Höganäs Colliery, the most important coal-mining undertaking in Sweden, which has just celebrated its 100th anniversary.

On the occasion of the jubilee of the French Society of Civil Engineers, two bulky volumes have been published tracing the development of the various branches of engineering from 1848 to 1898. The chapter on mining has been written by H. Couriot, § and that on iron and steel by H. Pinget.

G. M. Williams ‖ deals with mine legislation and mine inspection in the anthracite region of Pennsylvania, both from the historical and the present-day aspect.

Mine Surveying.—Some important contributions to mine survey-

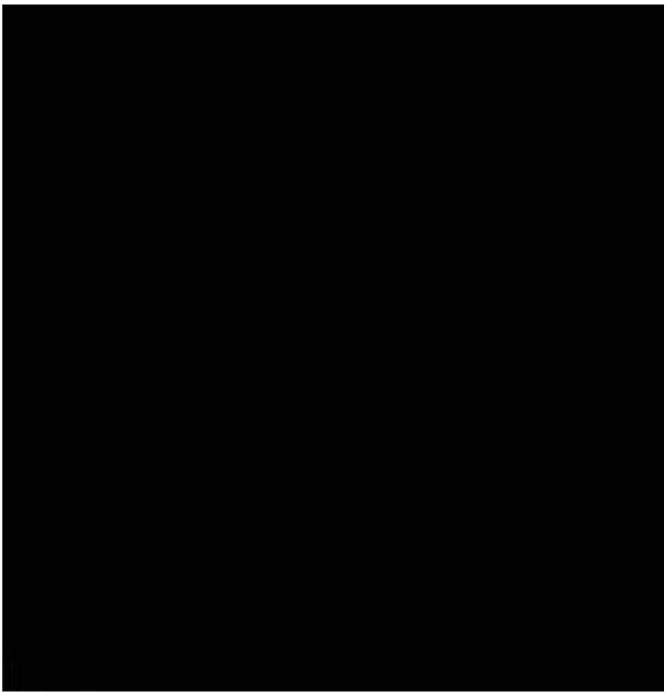
* *Europa's erste Steinkohlenbergbau.* (Aix-la-Chapelle: Ignaz Schweitzer.) 1898.

† *A History of Mining in the Black Country*, p. 133. Dudley, 1898.

‡ *Teknisk Tidskrift*, 1898, pp. 153–155.

§ *Bulletin de la Société des Ingénieurs Civils*, vol. li. pp. 1–507, and 513–888.

‖ Paper read before the International Mining Congress, Salt Lake City Meeting, July 1898.



brought by a creeper chain to a Schwidtal double tippler, which delivers the coal on to the lump screens. The coal which falls through this comes on to a Schwidtal horizontal double screen, which makes two sizes, large and medium. The greater part of the coal-dust is removed at this point, and carried to dust storage bins by a screw conveyor. The small coal is taken by an elevator to an oscillating screen, which separates the coal into nuts (firsts and seconds), pea coal (firsts and seconds), dust, and refuse. The further dust which separates at this point is also conveyed to the dust storage bins.

The round coal and the large lump and medium lump coal are conveyed by travelling belts into the railway trucks, while all the other varieties are carried along on endless belts to large storage bins, whence they can be directly loaded into railway trucks, which can be run in underneath the bins used for supplying the coal to the boilers, and for other requirements at the collieries, and for steam raising. The coal that is dirty and contains stone is conveyed by travelling belts to the stone breakers. Waste is either loaded as small coal or taken to the coal-washing plant.

The plant erected at the Deep Navigation pits of the Ocean Coal Company, Treharris, consists of: Steel pit-head gear; boxing or air-tight chamber; four patent tipplers; four fixed-bar screens; four Billy boxes; four jigging shoots; four patent picking belts, 5 feet wide; four anti-breakage loading jibs; four "small coal" conveyors; one 700-ton elevator; one revolving screen; one twin belt; five tub creepers; and one horizontal steam-engine, with a single 20 by 36 inch cylinder. A short illustrated description of the plant has appeared.*

The coal-washing plant at the Saint Eloy collieries, Puy-de-Dôme, is described.† The plant was erected in 1891, and almost all handling of the coal has been dispensed with. The description is illustrated by plans and sections.

A plant has been erected to deal with 2000 tons of coal daily at Toms Creek, West Virginia. Coal from the mines is tipped into a hopper, whence it is led downhill for a distance of 310 feet by a conveyor. The last 20 feet is arranged as a screen. Lump coal is delivered on to a picking belt 50 feet long by 4 feet wide, and then transferred by a lowering arrangement to the railway waggons, or is led to disintegrators when it is to be used for coking. The smaller

* *Iron and Coal Trades Review*, vol. lvii. pp. 593–594.
† *Génie Civil*, vol. xxxiii. pp. 328–330.

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eleven collieries worked by four lessees, and producing about 1½ million tons of marketable anthracite yearly.

Denomination.	Size of Mesh of Screen. Inches.	Tons.	Per Cent.
Lump	...	21,689	1·5
Steamboat	...	67,949	4·8
Broken	over 2¼	141,139	10·1
Egg	2¼ to 1¾	145,910	10·4
Stove	1¾ to 1¼	231,802	16·4
Chestnut	1¼ to ¾	265,897	18·8
Total large		874,386	62·0
Pea	¾ to ½	146,974	10·4
Buckwheat	½ to ¼	220,647	15·7
Rice	¼ and over culm screen	168,016	11·9
Total small		535,637	38·0
Grand total		1,410,023	100·0

Of the total output, 186,023 tons, chiefly of the small sizes, were used at the collieries. The change in shipping sizes is shown in the following table:—

Year.	Stove and Larger.	Chestnut.	Small.
	Per Cent.	Per Cent.	Per Cent.
1863	90·0	10·0	...
1868	87·9	11·2	0·9
1873	82·8	12·2	5·0
1878	77·2	12·5	10·3
1883	71·8	12·2	16·0
1888	69·9	11·8	18·3
1893	59·9	16·8	23·3
1897	48·0	21·7	30·3

The increase in the small size is due partly to the demand and partly to the large amount now saved from the waste heaps. Some particulars are given in the report as to the means adopted for this purpose.

The annual report of the Girard Estate, Pennsylvania, contains a description of a plant for washing anthracite waste erected on the estate last year. It was in continuous operation during the last five months of the year. The coal shipped was 17,897 tons, the proportion of each size (using the local nomenclature) made being: Chestnut coal,

2·02 per cent.; pea, 28·50; buckwheat, 37·32; and rice, 32·16 per cent.

C. Piez * describes the different methods of storing and handling the steam sizes of anthracite.

Coal Handling and Shipping.—Full illustrations are given † of the coal loading and unloading and storage plant erected at West Superior, Wisconsin. There are two buildings for anthracite, each 246 feet in diameter and 100 feet high, holding 50,000 tons, and an uncovered floor for 45,000 tons of bituminous coal. The coal is unloaded from the boats by grabs into conveyors and trimming-troughs, and is removed when required by a conveyor working in a cast-iron tunnel. The steel roof-girders offer several novel features.

Illustrations have appeared ‡ of the Werner apparatus for unloading coal, and also of the Wellman-Seaver plant. In the former an endless bucket conveyor is carried along a jib over the trucks and down a movable arm, which dips into the hold of a vessel. The latter plant is in use at the South Chicago Works for hauling the coal for the producers, and consists of elevated bins over which a crane travels.

The Hulett unloading machine is also illustrated.§ It has a grab to which a universal motion is given for removing coal from the hold.

There is on the American railways a marked tendency to increase the capacity of coal waggons from 60,000 lbs., which has been practically the standard for several years, to 80,000 lbs., and even more. Drawings of the new 80,000 lbs. coal waggons used by the Illinois Central Railway are published.‖ The special features of these waggons are the relatively low dead weight to the high live load, the increase in cubic capacity due to the side planking being placed outside the stakes, and the use of all-metal trucks.

J. Morison ¶ describes the Wrightson machine,** in which belts are used for conveying the coal to be loaded. It consists of a travelling truck, on which an endless belt carries the coal from the waggons to a second endless belt mounted on a jib. Suspended from the end of the jib, so as to dip into the hold of the vessel, is a trunk, through

* *Mines and Minerals*, vol. xviii. pp. 485–488.

† *Engineering News*, vol. xl. p. 99, with double plate.

‡ *Iron and Coal Trades Review*, vol. lvii. pp. 175–176.

§ *Marine Review* (U.S.), through *Iron and Coal Trades Review*, vol. lvii. p. 223.

‖ *Engineering News*, vol. xxxix. p. 378.

¶ *Transactions of the Institution of Mining Engineers*, vol. xv. pp. 67–71, with plate.

** *Journal of the Iron and Steel Institute*, 1897, No. II. p. 9.

which coal is lowered by a third endless belt or bucket conveyor. The capacity is 480 tons hourly.

H. Richardson * describes the waggon drops used for shipping coal at some points on the Tyne.

E. W. Crone † describes the telescopic spout used at the Wallsend staithes for preventing breakage.

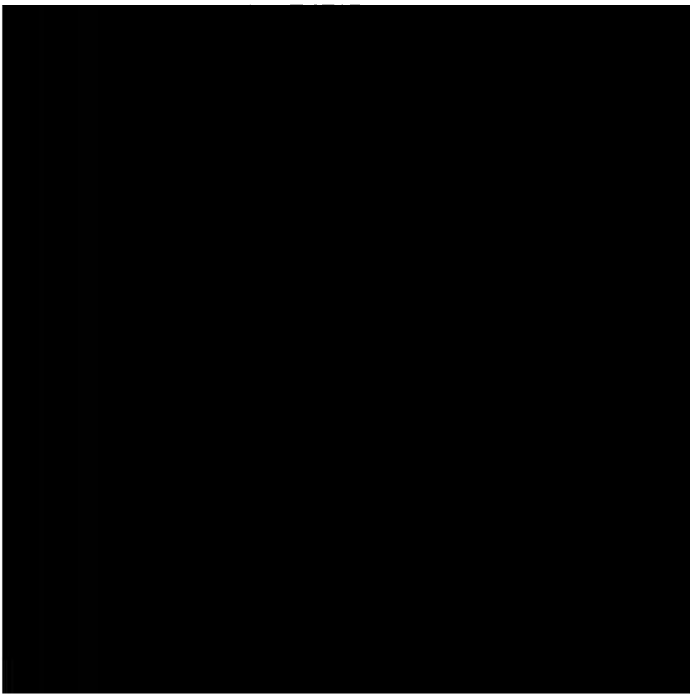
J. M. Moncrieff ‡ describes the coal-shipping plant at Wallsend Colliery, where steel boxes holding 5 tons each, mounted on light trolleys, are used. At the staithes these boxes are lifted by cranes off the trolleys, lowered into the hold, and tipped. The lines are arranged with gradients and automatic turntables to facilitate circulation.

W. B. Hanlon § describes the different types of coal unloading machines used at Lake Erie ports. His paper is illustrated by numerous excellent photographic illustrations, and contains an account of some of the earlier devices and of the improvements made up to the present time, including the Lindsay, the McMylar, the Long, the Brown, and the Webster, Camp and Lane machines.

Coke Briquettes.—A. J. Stevens ‖ describes the manufacture of coke briquettes. The paper is illustrated by a section of a typical artificial fuel plant, a view of the interior of a French artificial fuel plant with a double compression press, sections of the fuel press and of the pitch mill, and a view of Middleton's machinery for making fuel briquettes.

Peat-pressing Works.—A. M. T. Palmberg ¶ states that the Sparkjaer Peat Works, Jutland, are very large, consisting of one fixed and one floating factory with a small pressing department, while the conditions are favourable for getting the peat. The bogs are deep, the depth sometimes attaining 20 feet, and they are almost entirely free from roots and stems; but where the latter occur they are so decayed that they may easily be cut in two with the spade, while the peat is of medium quality. The diggers convey the raw peat, in trams running on rails and drawn by a small locomotive, to the cranes; and, after the peat has been worked up with water, it is raised by an elevator

* *Transactions of the Institution of Mining Engineers*, vol. xv. p. 74, with plate.
† *Ibid.*, vol. xv. pp. [illegible], with plate. ‡ *Ibid.*, vol. xv. pp. [illegible].
§ *Mines and Minerals*, vol. xviii. pp. [illegible].
‖ *Cassier's Magazine*, vol. xiii. pp. [illegible].
¶ *Jernkontorets Annaler*, vol. lii. pp. [illegible].



PRODUCTION OF PIG IRON.

CONTENTS.

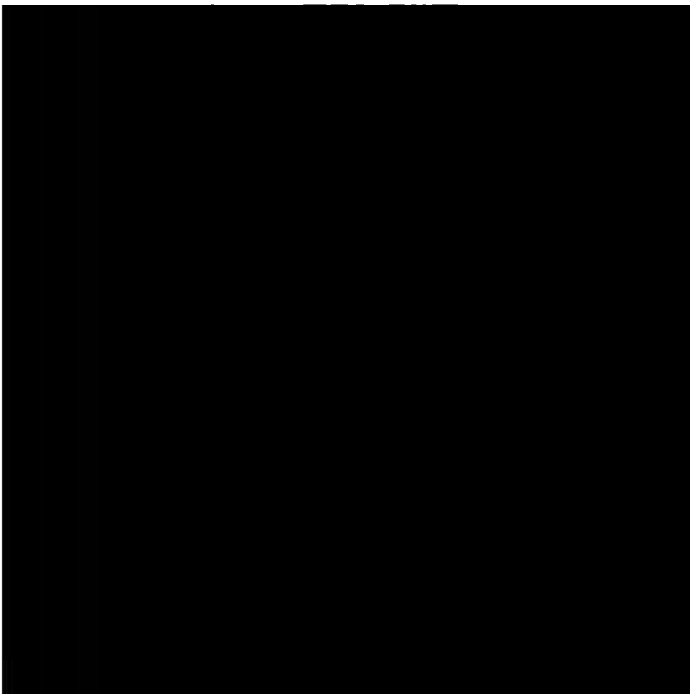
I.—*BLAST-FURNACE PRACTICE.*

The Calorific Balance of the Blast-Furnace.—G. Rocour * has published an exhaustive investigation of the calorific balance of the blast-furnace. The memoir occupies 97 pages, and deals with the previous investigation of the subject, with blast-furnaces working on white pig iron and on Bessemer or foundry pig iron, rapidity of the passage of furnace charges, utilisation of gas, Cowper stoves, boilers, and calorific analysis of the internal phenomena of the furnace. In conclusion the results are shown graphically.

Charging Blast-Furnaces.—F. Firmstone † gives a large number of illustrations made from actual measurements of the forms assumed by the charge in the blast-furnace as affected by various methods of filling. The forms observed are discussed, and the behaviour of the furnace in each instance is noted. In several instances the shape of the bells, &c., or the method of charging was altered, so as to change heaping up at the centre to an annular heaping, or *vice versâ*, partly to

* *Revue Universelle des Mines*, vol. xlii. pp. 1-97. Also published in book form, *Etude sur l'Equilibre Calorifique du Haut-Fourneau*, Liége, 1898. A copy of this work has been presented by the author to the Institute Library.

† *Transactions of the American Institute of Mining Engineers*, Buffalo Meeting, 1898 (advance proof).



perfect than that of coal, and the evaporative power being about as 6 to 4, it follows that the actual annual loss is half as much again.

The knowledge of the loss resulting in this way has led to many attempts to so improve the charging appliances as to eliminate it entirely, or rather as far as is possible, in practice. Quite twelve years ago attempts were made to this end in United States blast-furnace practice, and the author instances the arrangements of Kennedy and Scott and Fayette Brown. The first of these is applied to the Lucy furnace at Pittsburgh. These two appliances resemble each other in many respects, the ore, &c., being charged into a closed receptacle above the bell, which forms a movable base, and works in the usual way. A third somewhat similar arrangement is that recently designed in the United States by Suppes. All these three forms are described and illustrated. Taken on the whole, the author observes, they fulfil the requirements of the case. They are not too complicated, and enable a complete and accurate control to be maintained over the charging, while saving labour. A proper control of the furnace-working is, however, more difficult. They necessitate, too, a side take-off of the gas, and consequently in German furnaces, the author observes, their use will be limited, as when fine ore is being charged, at the moment of charging a considerable proportion would be drawn away into the side take-off. This would happen, for instance, in the case of purple ore, calcined spathic ores, soft brown hæmatites, &c., the velocity of the escaping gas being about 10 feet a second. The case, too, is different with German furnaces to that in the United States, for the ores are poorer and the production smaller, and it is often necessary to mix ten or more ores together in the ore mixture to be charged. The coke, too, needs to be strong to stand the repeated transfer from waggon to bell, bell to hopper, and hopper again to furnace. In Upper Silesia, therefore, these charging appliances are not likely to be of much use. In Westphalia the conditions are somewhat different, for there the coke is harder and firmer, and the ores often of a more lumpy character.

The appliance of Lewis, on the other hand, takes this question of the quality of the coke into consideration. The hopper above the bell is again closed, but the charge is made on to the hopper direct in the usual way through charging openings which close automatically. This, however, makes the arrangement more complicated, and prevents a proper supervision, as it is impossible to ascertain whether the whole of the charge has passed into the furnace, or whether the furnace has a

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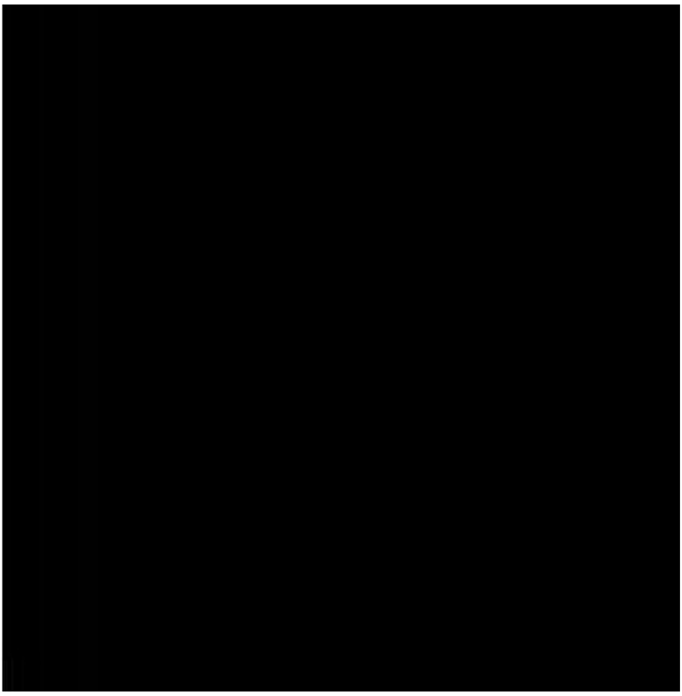
blowing, the charge hung up again. As much as possible of the charge was blown out, and it was then found that a bear had formed all round the boshes, narrowing conically towards the centre of the furnace. This adhering material was too low down in the furnace to admit of its being cleared away from above, and the attempt was therefore made to fuse it down, but this was also altogether a failure. A last attempt was therefore made to avoid blowing the furnace out, and desirable though this method proves to be, the author is not aware that it had been previously tried. The furnace was again blown empty to about the tuyere level, and small guiding openings, succeeded by larger working ones, were then made below the point at which the scaffolding had taken place in the furnace. The blast being shut off, these openings were carried right through the furnace walls, and through them the bear was knocked away. The first portion being knocked away, the remainder came down with a run, completely choking the four working openings. To be quite certain that the furnace was clear, these openings were then temporarily bricked up, and the furnace blown again until the charge had sunk quite below the openings. This took some hours, showing what a large quantity of material had collected in the furnace. The furnace was then again opened out, and the whole of the scaffolding, with the exception of a few small pieces of material that were then broken off, was found to have disappeared. The walls were quite clean, only a few dark spots on them showing where the mass had been adhering. The openings in the furnace were then properly bricked up, and the furnace put into regular blast again. It began at once to work properly, and continued satisfactorily afterwards.

The bear consisted of coke with some lime, and was filled up with a dusty kind of material. It showed but little resistance, and could be readily cleared away. There was no slag-like binding, and Van Vloten's carbon theory would appear therefore to hold good. Dealing generally with the question as to the cause of the hanging-up of charges, the author says he is generally in agreement with the theory propounded by Van Vloten.* His experience is that only those furnaces experience trouble from scaffolding which produce regularly one and the same kind of iron, whether white or grey. It is due to changes in the position of the reducing and carburising zones for the different varieties of iron, any scaffolding formed when one kind of iron is made being cleared away when another kind is produced. This is very

* *Journal of the Iron and Steel Institute*, 1893, No. II. p. 432.



at the tuyere level the coke is burnt directly to carbon dioxide, but that this is then immediately reduced to the monoxide. This is important as regards the temperature at the tuyeres, but it is of little importance as regards the temperature conditions within the furnace as a whole in what manner the carbon monoxide is produced. The amount of air required at the tuyere level for each pound of the carbon of the coke that is consumed must be constant: if the furnace is working steadily, it amounts to 5·75 lbs. The faster the air is admitted the quicker the coke is burnt, and the more rapid is the furnace working, and the inverse also holds good. The author in his calculations starts with the assumption that with a furnace working regularly under the same furnace conditions and with similar coke, the quantity of heat that must be evolved by the combustion of coke in the furnace remains identically the same for each ton of pig iron produced. If, therefore, it is desired to save some of this coke, heat must be introduced into the furnace from other sources, and this is effected by a prior heating of the blast. The author, before proceeding further into a theoretical consideration of this question, proceeds to describe the way in which the blast is heated. The stove he describes and illustrates is the Cowper. The temperature of the blast obtained by the use of this stove diminishes regularly with the time it is in use, thus in 1½-hour blow it fell in a case particularised from 910° C. to 840° C. The higher the temperature of the air blown into the furnace, the lower the quantity of coke consumed. The following figures relate to a general average per ton of pig iron produced at a plant in Lorraine that comprises three blast-furnaces.

Per Ton of Pig Iron made.

	Tons.
Dry air blown in	3·600
Coke consumed	1·021
Carbon in coke	0·825
Carbon converted into carbon monoxide at the tuyeres	0·626
Carbon consumed	0·199
Carbon in pig iron	0·036
Carbon in waste gases	0·789
Temperature of blast at stoves	870° C.
Temperature of blast at tuyeres	800° C.
Temperature in upper part of stove	1100° C.
Waste heat	350° C.

The author makes use of these figures as the basis of an elaborate calculation, which shows the high value to be attached to heating

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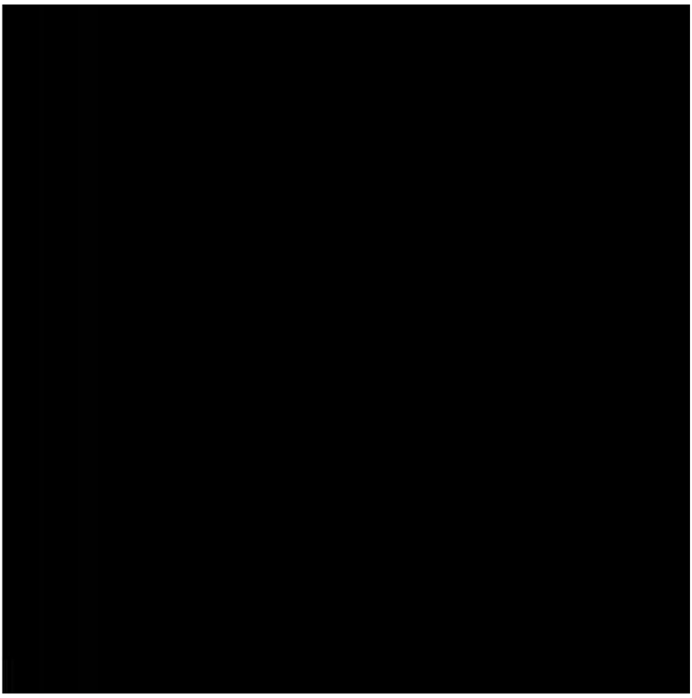
engine built by a firm in Ohio. The steam cylinders are 42 and 78 inches in diameter. The air cylinders are 88 inches in diameter with a 5-foot stroke, and are suspended on the under side of the bed-plate to reduce the height. The connection to the fly-wheels is made through rocking-shafts.

Casting Pig Iron.—The blast-furnace plant now in course of erection* at Lorain, Ohio, is to be furnished with a novel casting-plant. The metal not used for the converters is taken by 15-ton ladles to a point about 1250 feet distant from the furnaces. Here the ladles run on a slightly elevated track, and discharge the metal into a swivelling spout which extends over a lower track on which the pig moulds are run. The moulds are of cast iron, carried on small trucks weighing altogether 10 tons. Five of these trucks, which are built so as to overlap, are made up into a train and drawn under the spout. There are three rows of moulds on the trucks, and each row is filled simultaneously. Then the train is run into a siding, while the pigs cool for about three hours, and subsequently the train carries them to the storage yard, where each truck is picked up by a crane and emptied.

Illustrations have been published † of the Baker apparatus and of the Davies apparatus, both of which are to be used in place of pig beds for casting pig iron. In both the plant is placed at any distance from the furnaces, and the molten iron is carried to them in ladles. The Baker plant has the moulds arranged as beds mounted on trunnions and tipped by hydraulic rams so as to discharge the pigs when sufficiently solid into a hopper over the railway trucks. The ladle trucks run on an elevated line at one side of the line of moulds, and the metal is poured through a runner which reaches over the centre of the mould. In the Davies plant the moulds are mounted on rough trunnions on the circumference of a large horizontal wheel. As the wheel revolves they are automatically tilted by striking a fixed tappet when they come over the hopper or shoot. The moulds are double, one mould being on the top and the other on the bottom of the casting, so that as the upper moulds are being filled those on the underside can be sprayed ready to receive the iron when they are turned up.

* *Iron Trade Review*, vol. xxxi. No. 27, pp. 11–16; *Engineering and Mining Journal*, vol. lxvi. pp. 189–190.

† *Iron and Coal Trades Review*, vol. lvi. pp. 974–975; *American Manufacturer*, vol. lxii. p. 763; *Iron Age*, vol. lxi. May 19, pp. 13–14.



ladle, which is semi-circular on its under surface, rolls forward and pours out the slag. It is kept in its true path by chains wrapped round it in opposite directions, which form a cheap and efficient substitute for rackwork.

Mixers are largely used to render the metal uniform, and at the Cleveland Rolling-Mills a semi-cylindrical mixer holding 120 tons is in use, revolving about its longitudinal axis on rings of live rollers. Oil, steam, and air are injected at one end to keep the bath warm. Two hydraulic rams tilt it in one direction or the other.

J. Birkinbine * has drawn up a report on the manufacture of iron and steel at Marquette from the ores of that district. Fuel will have to be brought to the furnaces, and it is still a problem of the future as to whether it is better to carry the raw coal or to coke it before transport. Flux of suitable character is to be found in the neighbourhood. A comparison is made of the cost of manufacture at Buffalo, Cleveland, and Marquette, in favour of the latter, and also Chicago and Pittsburg are compared with the same locality. It is not forgotten that these centres also use the Lake Superior ores, and therefore would be competitors. It is considered that not only pig iron should be produced, but also that steel plant and rolling-mills should be erected.

J. Bowron † deals generally with the manufacture of iron at Birmingham, Alabama, and shows the natural advantages possessed by this district.

W. P. Hunt ‡ advocates the resumption of iron manufacture in New England, as the question of freight is greatly in its favour. Ores could be obtained at Boston from Cuba, Newfoundland, and Nova Scotia, whilst coal of coking quality might be brought from Cape Breton. Limestone of suitable nature is available in the vicinity.

The Working of the Dover Furnace, Ohio.—A. K. Reese § gives some notes on six months' working of the Dover furnace, Ohio. This furnace is 75 feet high, 16½ feet in the boshes, 10½ feet in the hearth, and 12½ feet at the stock line. It has three Cowper stoves 65 by 16 feet. The coke used shows on the average—

Volatile Matter.	Ash.	Carbon.	Silica.	Alumina.	Sulphur.
3·65	12·42	83·12	4·43	2·52	0·71

* Pamphlet, p. 31, Ishpeming, 1898.
† *Journal of the American Foundrymen's Association*, vol. v. pp. 4–17.
‡ *American Manufacturer*, vol. lxii. pp. 439–440.
§ *Transactions of the American Institute of Mining Engineers*, Lake Superior Meeting 1897 (advance proof).

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bottom inclined at 45°, being made of 1½-inch cast-iron plates. The ore carriers run in front of the bins in a pit 10 feet wide and 30¾ feet deep, being supported from an electrically driven truck provided with a weighing appliance, and running on rails 6 feet below the surface. The man working this truck can open the doors of the bins by a foot lever and draw off weighed quantities of ore, which are then taken to the hoisting skip of 8 tons capacity.

The furnaces, two in number, will be 100 feet in height, 14 feet diameter in the hearth, 22 feet in the boshes, and 15 feet in the throat. Each has sixteen 6-inch tuyeres and copper cooling plates. The shells will have a diameter of 31½ feet, and the stack is carried on eight steel columns, 22 by 18 inches and 35½ feet high, resting on a cast-iron ring made in eight 9-ton sections.

The hoisting incline will be a firmly trussed structure, rising at an angle of 60° and carrying a skip of 225 cubic feet capacity, or about 8 tons of ore. The skip travel in each trip will be 210 feet, and an average of 15·75 skip loads per hour will be delivered at the top of the stack. The calculations as to materials are based on 188 loads per day—94 for ore and limestone and 94 for coke.

The top is closed by means of the usual bell and furnace hopper. A conical seal, made in six sections, is bolted to the top of the furnace hopper. It is provided with six 18 by 24 inch explosion doors. This seal prevents the escape of furnace gases when the bell is lowered for the purpose of allowing the charge to pass into the furnace, and the explosion doors provide for relief in case of emergency. The sections of the seal are bolted together, and may be easily and quickly removed for renewal of the bell or hopper rings. Above the seal, carried by a truck travelling on girders supported by columns from the furnace platform, is the distributing apparatus. The distributor consists of a hopper of sufficient capacity to hold the several maximum charges of coke, ore, and limestone. The hopper is cylindrical, with flared top and built in two sections, one suspended from the beams of the truck, and carrying the bell, while the other section, a little larger in diameter, is arranged to rest on the top flange of the furnace seal, when stock is received from the skip. This outside ring is lifted by a steam cylinder on the truck to allow the stock to drop on to the furnace bell.

On the same track girder which carries the distributor, and on rails outside of the distributor tracks, is a gantry crane of 20,000 lbs. capacity, which may be transferred to any position without interference with the top mechanism, and can be used for lifting readily any parts which

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The First Coke Blast-Furnace in Europe.—O. Vogel,* in considering the various suggestions as to which was the first coke blast-furnace in Europe, draws attention to a still earlier experiment than any which has yet been mentioned. This took place in Germany in 1750. Brown coal from the Westerwald was coked. Four thousand German pounds of this brown coal was first coked in a meiler. There resulted 1449 lbs. of "coke," and other attempts subsequently followed, with varying results. Unsuccessful experiments with this fuel were then made at the Heiger Ironworks.

Russian Ironworks.—J. Thieme† gives details of the costs of a Russian blast-furnace, Coppée coke-oven plant, and Bessemer plant. The blast-furnace had a capacity of 12,643 cubic feet, and its cost, including stoves, boilers, blowing-engines, and plant generally, was £65,973. The cost of construction of the battery of sixty Coppée coke-ovens, with its accompanying coal-weighing plant, was £32,434. The Bessemer plant had a yearly outturn of 57,377 tons, and its cost was £31,394.

Dealing next with some of the blast-furnace plants, the author describes the Kamenski Works of the Dnieper Company. At this works the year's production included—

	Metric Tons.
Coke	85,686
Pig iron	138,170
Spiegeleisen	18,350
Bessemer steel	73,860
Open-hearth steel	43,360
Malleable iron	10,430
Steel rails	55,350
Other products	54,080

Thus from every 100 tons of pig iron there was obtained 82 tons of steel ingots and billets, and 70 tons of finished products. In the iron ore mines belonging to this company 3,400,000 tons of ore is in sight. At these works four blast-furnaces are in blast, three of which average each 131 tons of pig iron daily, and the fourth 82 tons. The three larger furnaces are each 67 feet in height, and the other 52½ feet. The hot blast is obtained by the aid of eight Whitwell stoves, each 59½ feet high, and six Cowper stoves, each about 76 feet high. The stoves are all about 22 feet in diameter. There is a foundry attached, and

* *Stahl und Eisen*, vol. xviii. pp. 534–535.
† *Ibid.*, vol. xviii. pp. 714–718, 761–766, and 800–806, with numerous illustrations.

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that are in use. Whitwell stoves were formerly employed. The Hartman system of heating boilers with blast-furnace gas is in use. This is illustrated and described in some detail. The blowing-engines are also dealt with.

G. Kamensky* describes the iron industry of the Ural. The various ore and coal deposits are described, the questions of fuel and transport are discussed, and the cost of the manufacture of pig iron is dealt with in some detail.

II.—*CHEMICAL COMPOSITION OF PIG IRON.*

Austrian Pig Iron.—C. F. Eichleiter† gives the following results of analyses of pig iron from the Prince-Bishop's Works at Friedland:—

	I.	II.	III.
Carbon	3·99	3·91	4·14
Sulphur	0·10	0·06	0·05
Silicon	1·63	0·54	0·93
Copper	0·013	0·011	trace

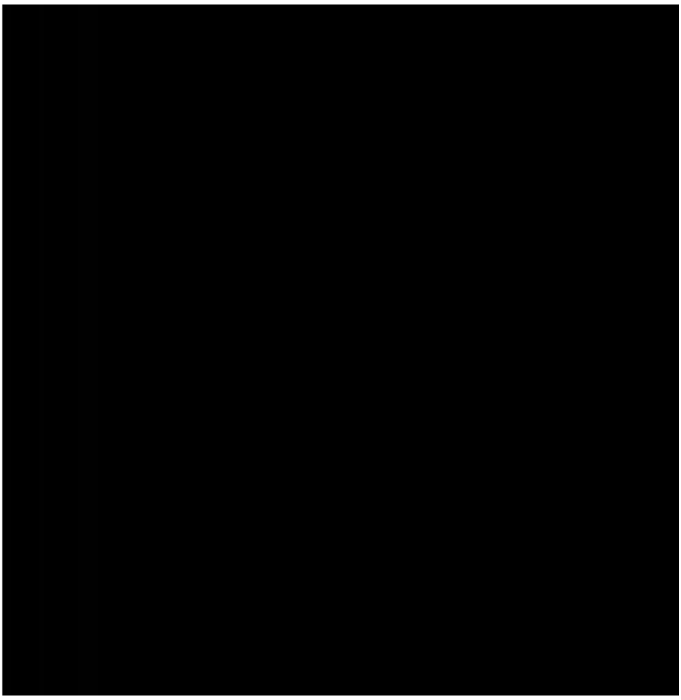
I. Grey pig iron; II. White pig iron; III. Grey pig iron.

Two other specimens of pig iron from the same works yielded—

	IV.	V.
Combined carbon	0·53	0·53
Graphite	2·77	2·62
Silicon	1·84	0·71
Phosphorus	0·97	1·84
Sulphur	0·11	0·10
Nickel	trace	0·06

Pig Iron from Pyritic Ores.—Experiments are stated by Tholander‡ to have been made in Sweden for the manufacture of grey pig iron low in sulphur from pyritic ores. These ores were first calcined at a low temperature, and finally at a high temperature, in a Westman kiln. After this treatment, they contained 0·16 per cent. of sulphur,

* *Colliery Guardian*, vol. lxxvi. pp. 28–29.
† *Jahrbuch der k.k. geologischen Reichsanstalt*, vol. xlvii. pp. 751–752.
‡ *Jernkontorets Annaler*, vol. lii. pp. 354–355.



Utilisation of Slag.—Some tests* have been made of the relative values of road-making materials by subjecting 4 lbs. of each sample to wear both wet and dry in a barrel revolving twenty times a minute for 8000 revolutions. The loss of weight of slag was between that of Newry and Guernsey granite, as shown by the following percentages:—

	Dry Test. Loss in Weight per Cent.	Wet Test. Loss in Weight per Cent.	Specific Gravity.
Enderby granite	4·15	5·47	2·64
Newry granite	9·52	19·14	2·78
Guernsey granite	7·95	14·45	2·94
Blue Pennant stone, Pontypridd .	14·45	27·54	2·68
Iron slag, W. H. Butlin, Ironworks, Wellingborough . . .	8·20	15·72	3·02

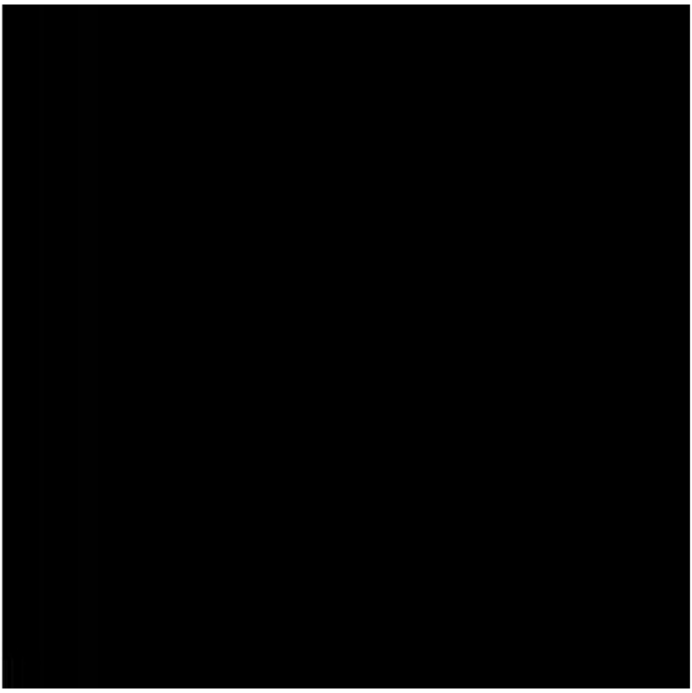
Slag Bricks.—According to R. Helmhacker,† slag bricks are successfully made at Kralovedvoor, thirty miles west of Prague. The blast-furnace slag used contains—

SiO_2.	FeO.	Al_2O_3.	CaO.	MgO.	MnO.	S.
25·8–27·0	1·5–1·7	17·3–19·3	51·4–51·5	2·5–0·4	0–0·1	1·3–1·8

To granulate the slag, it is run into an inclined cast-iron trough, into which cold water also flows, the amount being regulated to produce a sharp sand. Much of the sulphur is driven off during this treatment. The sand is removed by perforated bucket-conveyors to mixers, where well-slaked lime, made into a paste with water, is added. The mixed material is made by a press into bricks, weighing about 10½ lbs. each, at the rate of a thousand hourly. They are dried for eight days, or longer in wet weather, and will then sustain a load of about 250 lbs. per square inch.

At Ekaterinoslav, Russia, slag bricks are made from granulated slag, ground, and mixed with 4 to 10 per cent. of lime. The materials are mixed dry, and then pressed. The tensile strength is about 312 lbs., the crushing strength from 1250 to 5600 lbs. per square inch, according to the time of hardening. Approximate analyses of the granulated slags show: Silica, 22·5 to 35·0 per cent.; alumina, 14·0 to 15·0; iron, 3·3 to 1·1; manganese, none to 0·3; lime, 51·0 to 45·0; magnesia, 1·4 to trace; sulphur, 0·3 to 0·4; loss on heating, 7·5 to 2·3 per cent. The bricks are really slag cement moulded into shape and set.‡

* *Iron and Coal Trades Review*, vol. lvi. p. 824.
† *Engineering and Mining Journal*, vol. lxv. p. 460.
‡ *Clay Worker*, through the *Engineering and Mining Journal*, vol. lxvi. p. 394.



is hard in about ten hours. The results of mechanical tests are also given.

A slag brick plant is intended to be laid down at the Kamenski Works, but here the matter is still in the experimental stage.

IV.—*FOUNDRY PRACTICE.*

Variations in Cupola Design.*—The efficiency of a cupola for melting iron depends principally on the following points:—1. In the quantity of metal melted in a given time. 2. In the quantity melted in a given size of cupola. 3. In economy or the ratio of fuel used to each ton of iron melted. 4. In the ease and certainty of melting. 5. In continuous melting as long as desired. 6. In giving perfect castings to the end. 7. In freedom from clogging or hanging. 8. In small destruction of lining. 9. In a small waste of chilled iron and fine shot. 10. In a small absorption of sulphur. 11. Minimum labour in preparing and in shovelling out refuse.

It is generally supposed that the uneven distribution of the blast is the greatest drawback to obtaining the best economy of fuel. No very sharp lines of demarcation can be drawn, but cupolas may roughly be divided into the following classes:—1. Cupolas attempting economy through the arrangement or shape of their tuyeres. 2. Cupolas attempting economy by alteration of their vertical section. 3. Cupolas employing hot-blast or utilising the escaping gases. 4. Cupolas employing induced draught. 5. Cupolas fired by gas. 6. Cupolas arranged for the injection of oil, coal, or other substances. A short description is then given of the cupolas known under the names of Bocari, Fuller, Thwaite, Whitcomb, Blakeny, Krigar, Lawrence, Paxson-Colliau, Prince, Whiting, Hibler, West, Johnson, Massey, Voisin, Greiner and Erp, Nau-Hebertz, &c.

B. S. Summers† discusses modern cupola practice, with special reference to the discussion of the physics of cast iron. The effect of sulphur, silicon, phosphorus, manganese, carbon, combined carbon, the influence of oxidised material, especially rusty scrap, upon mixtures.

* Iron and Coal Trades Review, vol. lvi. p. 601, vol. lvii. pp. 135, 179, 736, &c., with illustrations.

† Transactions of the American Institute of Mining Engineers, Buffalo Meeting, 1898 (advance proof).

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neck of the roll is made in a sleeve which slides into the chill mould far enough to make the shortest roll required.

Recovering Iron from Cupola Slag.—W. J. Keep * deals with the recovery of iron from cupola slag. The material is crushed and run through a drum washer, which retains iron shot, &c., whilst the slag and coke are carried away by the water flowing through the mill. This plant is compared with an old form of trommel which was used for the separation. In the new arrangement 2928 lbs. of iron was recovered from 8280 lbs. of slag after large pieces of iron had been picked out. This amount was produced by melting 60 tons in the cupola.

Specifications for Foundry Castings.—Some specifications adopted for foundry castings have recently been published.† The chemical requirements are as follows, exceptions being made for particular cases which are mentioned :—

	Silicon.	Sulphur not to Exceed	Phosphorus Below	Manganese not Above
Hard	1·20 to 1·60	0·095	0·70	0·70
Medium	1·40 to 2·0	0·085	0·70	0·70
Soft	2·20 to 2·80	0·085	0·70	0·70

The physical tests are also given. The transverse strength is taken of an inch square bar on supports 12 inches apart. The following table shows the limits for the properties mentioned :—

	Transverse Strength not Under	Deflection not Under	Shrinkage on 12 Inches not Under	Chill not Over
	Lbs.	Inch.	Inch.	Inch.
Hard	2400	0·08	0·161	0·25
Medium	2200	0·09	0·151	0·15
Soft	2000	0·10	0·141	0·05

C. W. Friend ‡ gives some fluidity and hardness tests of various

* Paper read before the National Association of Stove Manufacturers, through the *Iron Age*, vol. lxi., June 9, pp. 6–7.

† *Iron Age*, vol. lxii., September 29, pp. 4–5.

‡ Paper read before the Pittsburg Foundrymen's Association, March 1898, through the *American Manufacturer*, vol. lxii. pp. 440–441.

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an elevated track on one side. Three cupolas, 84, 72, and 54 inches in diameter, are provided, and five jib-cranes are used to handle the material.

A. Ledebur * describes and illustrates the Westinghouse Brake Foundry, and various foundry appliances are also referred to or described.

A Chinese Foundry.—Some photographic views of a Chinese foundry have recently been published.† A somewhat chaotic condition of the floor and elementary appliances is shown. One cupola, about 6 feet in height, is made in three portable sections, and supplied with blast by hand-bellows, through a single tuyere.

Foundry Appliances.—S. H. Stupakoff ‡ advocates the use of labour-saving appliances for handling pig iron, sand, and coke in the foundry; flasks of adjustable size, and otherwise improved, to enable them to be more easily handled, used, and stored; the use of moulding machines, pickling, sand-blast, and chipping-tools for cleaning and dressing castings; sand-mixers, and other apparatus.

H. M. Kamp § advocates overhead trolleys for handling material in foundries in preference to travelling cranes. The trolleys run on single overhead rails, and can carry with air-lifts or other arrangements. Much discussion ensued.

Drawings are published by F. Freytag ‖ of a 12-ton travelling foundry-crane of special construction. Two cranes of similar design, but of 5 tons capacity each, were shown at the Leipzig Exhibition.

At a wheel foundry in Reading, Pennsylvania, a very complete electric plant has been laid down to work the cranes, blowers, and other machinery.¶ An account has also been published ** of various recent improvements in foundry appliances.

Moulding.—G. E. Mathews †† describes a portable pneumatic rammer

* *Stahl und Eisen*, vol. [illegible] pp. 461–467.

† [illegible] No. 11, pp. [illegible]

‡ [illegible] *Foundrymen's Association*, vol. iv. pp. 146–155.

§ [illegible]

‖ [illegible] *Engineer*, vol. xiii. pp. 386–387, with seven illustrations.

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** [illegible] vol. [illegible] pp. 7, 31.

†† [illegible] *Foundrymen's Association*, vol. iv. pp. 275–282, with illustrations.

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PRODUCTION OF MALLEABLE IRON.

Puddling Furnaces in South Russia.—J. Thieme * states that at the Kamenski Works there are five double puddling furnaces with step grates, five others of the Dnieper Works type, with producer and recuperator, and two rotating Pietzka furnaces. At the Donezko-Jurjewski Works there are twelve puddling furnaces of ordinary type taking 0·32 ton charges. The pig iron used is taken direct in the molten state from the mixers.

Iron Manufacture in China.—An illustrated account, largely consisting of quotations from Richthofen, has recently appeared on the iron industry of Shansi. Iron ores occur abundantly in several strata of the coal formation. The Chinese use only one kind of ore, which melts easily without the addition of any flux. It consists of a mixture of clay iron ore and spathic ore together with limonite and hæmatite, and occurs in irregular accumulations in certain limestone strata, at the bottom of the coal formation. Tai-yang-chin, 60 li north-west of Tse-chau-fu, and Kau-ping-hien are the only places where all the iron produced in the district is melted from the ores. Nothing at all approaching in appearance a European blast-furnace is in use. The smelting-place is an inclined plane, 8 feet long and 5 feet wide. It is enclosed on the two long sides by loam walls 4 feet high, the third side and the top are open, and on the fourth side it joins a small and low hut which contains the wooden bellows and the two men who work it. The floor is covered with a layer of small pieces of anthracite. Upon this are put about 150 crucibles of fireclay, 15 inches high and 6 inches wide, containing a mixture of small pieces of anthracite with crushed iron ore. All spaces between them are carefully filled with anthracite and another layer of pieces of this fuel put on the top. In some other regions the smelting-places are 15 by 5 feet, and contain

* *Stahl und Eisen*, vol. xviii. pp. 761 and 806.

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by half-a-dozen men with goat-skin bellows working nearly all day long, and the molten metal runs out. The metal cannot be forged, and is only used for primitive agricultural implements. A day's work yields about 75 lbs. of metal, and the workmen earn the equivalent of about three farthings daily.

Iron Manufacture in Ethiopia.—At Finfani in Ethiopia iron ore is worked open-cast from apparently rich deposits. The native furnace for smelting them is of funnel shape built of clay, with a capacity of 9 to 11 gallons. Blast is supplied by four buckskin bellows worked by two men. When the furnace is well alight, ore broken into small pieces and mixed with charcoal is charged in, and a metal plate sealed with clay is used to close the mouth of the furnace except for the blast opening. The sponge produced is removed from the furnace, cooled, broken up into fragments, and again charged into the furnace. During this second operation the bellows are placed at the upper instead of the lower part of the furnace. The bloom is withdrawn when it has assumed a pasty condition, and is shingled on a flat stone serving as an anvil, and reduced to broad thin cakes weighing from 16 to 19 lbs. A high quality of metal is produced, and is worked up into bits, [illegible], ploughshares, swords, and tools. Wood only is used, although an outcrop of coal is known at [illegible], two days' [illegible].*

Iron Manufacture in the Congo.—In a short geological account of the Congo, [illegible] quotes a description [illegible] of native iron manufacture in the basin of the [illegible]. The furnace is [illegible] in height, blown through a single [illegible] at the back. [illegible] and charcoal are used. The blooms produced are hammered on [illegible].†

History of Iron.—[illegible] in the [illegible] [illegible] the great [illegible] [illegible] metals [illegible] iron was [illegible]

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[illegible] *Institution of [illegible], vol. [illegible]

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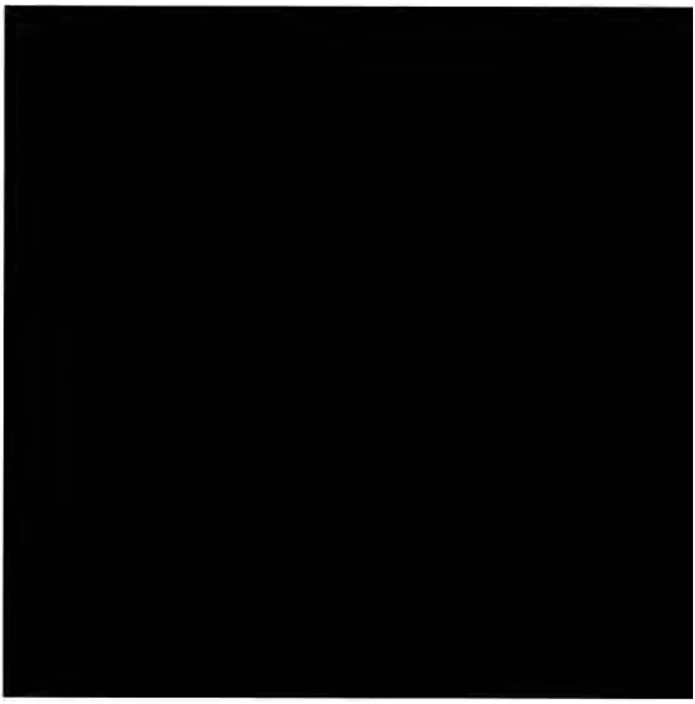

C. Fremont * gives the results of some observations of the work done in hammering. The kinematograph was used to observe the path of the hammer, and formed a basis for calculation. The results are given for hammers of various weights, ranging from hand-hammers to sledges. The work done in exceptional cases ranges as high as 200 foot-lbs. per second, but the more usual range is 100 to 150 foot-lbs.

The Use of Presses.—The use of presses instead of steam hammers is discussed by E. M. Daelen.† In the case of hammers, he observes, the work is done by percussion, and in such treatment a harder material always causes a certain effect on a softer one. The outer surface of the ingot may in this way be stretched without the action passing through to the ingot core. The action of the press is very different. If the ingot is too large the press simply remains at rest upon it. The advantage is distinctly with the press as regards good results, and the author describes the different forms of press that have been designed, together with the methods for the indirect utilisation of steam as the source of power, an arrangement devised by himself being specially referred to.

Forging Steel Shafts.—G. H. Bryant ‡ states that Krupp's method of making steel shafts is to cast the ingot three times the size of the finished shaft, reduce it by hydraulic forging machines, and finally to bore out the centre when cold. From the time the ingot is cast until the shaft is finished, the work is not allowed to get cold. In American practice the ingot is cast twice the diameter of the shaft, cooled, bored, reheated, and forged hollow, but objections are taken to this method in favour of that of Krupp.

Electric Power in Rolling-Mills.—E. B. Clark § deals with electric transmission of power in rolling-mills, and gives some diagrams of the load curve during twenty-four hours. The current may be used for lighting, for driving series motors, for cranes, hoists, conveyors, charging machines, table rollers, transfer trucks, &c.; for driving shunt motors operated intermittently for lathes, shearing machines.

* [illegible], vol. [illegible] pp. 671-733, with illustrations.

† [illegible], vol. xiii. p. 732.

‡ Paper read before the Western Society of Engineers, through the *Iron Trade Review*, vol. [illegible] No. [illegible] p. [illegible]

§ Paper read before the Western Society of Engineers, through the *Iron Age*, vol. lxii. No. [illegible] pp. [illegible]

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were turning out more than three times this quantity of even ½-inch plates per shift, while other mills rolling ⅜-inch plates and upwards turned out as much as 120 tons per shift. It was by such developments as these that great economy had been brought about.

Wire-Rod Mill with Roller-Bearings. — A wire-rod mill has recently been erected * at Bay Way, near Elizabeth port, New Jersey, in which the finishing mill is fitted with roller bearings. In the mill the bars, 3½ inches square and 4½ feet long, are brought down to a ⅞ inch billet in eleven passes in one set of three-high rolls and one set of two-high rolls. This mill is 16 inch, and runs at 100 revolutions. The intermediate mill is a three-high 10-inch mill with three stands of rolls, running at 250 revolutions, and here the rod is reduced to ⅜ inch. The finishing mill consists of six stands of three-high 9-inch rolls, driven at 350 revolutions. The capacity when rolling two ¼-inch rods is 80,000 to 140,000 lbs. The bearings each contain twenty-four steel rollers 6 inches long and 11/16 inch in diameter, held by a cylindrical cage.

Tables for Rolling-Mills. — Illustrations have appeared † of rolling-mill tables.

[illegible] ‡ also describes and illustrates a new form of lifting table for trains of rolls. It only lifts at one end, pivoting at the other.

Sharp's Taper Rolling-Mill. — Illustrations have appeared § of Sharp's taper rolling-mill. It is a two-high mill with the upper roll adjustable as usual by screws, and is geared to the lower roll by spur pinions. The lower roll is driven by racks engaging pinions on its necks, and these racks are reciprocated from a crank shaft. During the reciprocation of the racks the driven roll is lifted or lowered by means of [illegible] arranged upon the rack carriers and under [illegible] the roll bears, thus producing the necessary lifting [illegible] of the roll during its rotation by the rack [illegible] longitudinal motion of the bar or plate.

The [illegible] Mill. — An illustrated account of the

* [illegible]

† [illegible] vol. [illegible] pp. [illegible] and [illegible]

‡ [illegible] with illustrations.

§ [illegible] vol. [illegible]

[redacted]

[illegible]

[redacted]

ances and the quickness of the work referred to. At Lorain the housings, rolls, bearings and chocks, weighing 40 tons, are picked up bodily by an overhead electric crane, and deposited in a special shop, while a similar set, built up on a dummy bed-plate, is carried over and dropped in its place. The entire stoppage of a mill for roll changing is one hour. The sawing of a rail, say 100 feet or over, into three lengths, is effected in one operation by four saws which advance simultaneously.

A large condensing plant forms part of the equipment of many modern steelworks. It takes the steam from all mill and auxiliary engines, and in spite of irregular working of any individual engine, gives on the average a constant vacuum.

The application of electrical apparatus, especially to cranes under most trying conditions of heat, dirt, and occasional overloading is steadily increasing, and it is found that this class of machinery gives very little trouble.

At the Pencoyd Iron and Steel Works, near Philadelphia,* the blooming mill is a [illegible] two-high reversing mill driven by a pair of [illegible] engines geared [illegible]. The tables are equipped with [illegible] manipulators. The mill and engine are surmounted by a [illegible] electric travelling crane, and provided with a [illegible] for changing the rolls. The mill is fed by four vertical [illegible] furnaces of the regenerative type fired with producer gas. The [illegible] of the blooming mill supply three finishing mills and the [illegible]. [illegible] goes to the beam mill which [illegible] the other mills receive their charges [illegible] the beam mill [illegible] regenerative heating furnaces [illegible]

[illegible]

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PRODUCTION OF STEEL.

CONTENTS.

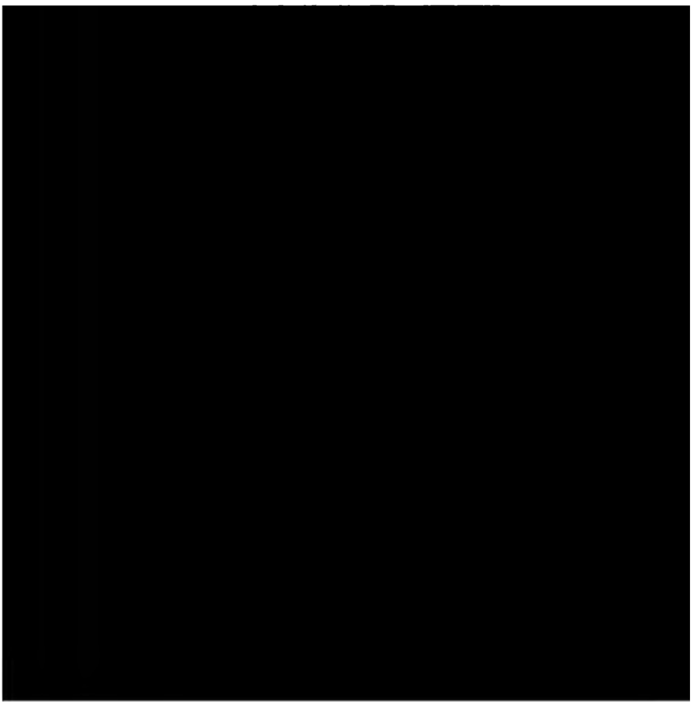
I.—*THE CARBURISATION OF MALLEABLE IRON.*

Crucible Steel Furnaces.—An illustration has appeared * of the ten-hole crucible furnace at the works of the Crescent Steel Co., Pittsburg. Each hole takes six crucibles and is fired with natural gas. The outturn is 18 tons in six heats daily. The works also possess two four-hole and two six-hole furnaces.

According to Eisenbach,† Piat's old form of crucible furnace was provided with an additional crucible with perforated bottom into which the metal to be melted was placed, the metal not being melted in the proper crucible itself. In this way, by a perfect separation of the metal from the fuel, while the metal itself was directly in contact with the flame, a more rapid fusion resulted, as well as a saving in fuel. The crucible, too, lasted longer, and labour was also saved. Still, despite these advantages, the furnace did not find much favour in many kinds of foundry work, the result being that it was subjected to a lengthened series of experiments. A result of these is the Baumann furnace. This is made in two forms, one of which serves as a crucible furnace for the melting of iron and other metals and alloys, and the other as a rapid cupola. Both these forms are now described and illustrated. The first form is of the tipping type

* *Iron Trade Review*, vol. xxxi. No. 20, p. 11.

† *Stahl und Eisen*, vol. xviii. pp. 547–551, with four illustrations.



castings in the United States is from 80,000 to 100,000 tons. The extensive use of steel castings for the Navy, and the possible future of the manufacture of cast-steel guns, are also mentioned.

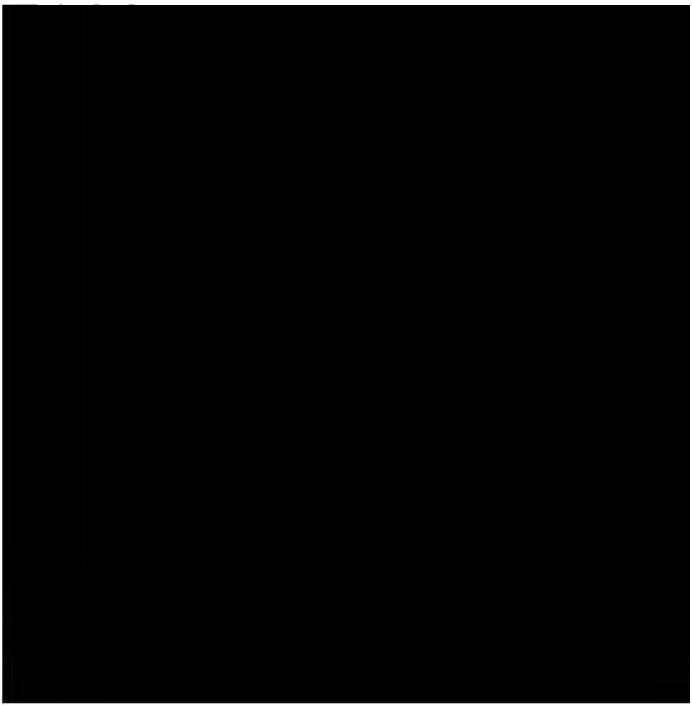
II.—*THE OPEN-HEARTH PROCESS.*

Economy in Furnace Working.—On the Continent a considerable amount of attention is now being devoted to economy in fuel in furnace working, and F. Toldt's * treatise on regenerative gas furnaces is one of the most important contributions to the literature of the subject that has yet appeared. In 440 pages it gives an exhaustive description of the scientific data on which the calculation of the dimensions of furnaces should be based. The treatise is divided into three sections —the first deals with fuels, solid, liquid, and gaseous, and with electric energy, and with the theory of combustion; the second, with the details of regenerative furnaces; and the third, with the calculation of the dimensions of various types of furnace, the examples selected being open-hearth furnaces, coke-ovens, gas puddling furnaces, hot-blast stoves, and regenerative furnaces with oil firing.

The calculation of the dimensions of a furnace burning petroleum residue is specially interesting, in that this product is now being obtained at Baku in vast quantities. The author shows that, as a rule, petroleum is economical as fuel when its price at the works per unit of weight is equal to or less than 2·6 units of weight of coal.

In a well-bound volume of 142 pages E. Damour † has summarised his important memoirs published at various times in French technical journals. The result is a book of reference of a thoroughly practical character on the important subject of economy in furnace heating. It is the work of an engineer of long experience in operations of that kind, but at the same time full cognisance is taken of the progress of science, for the author is able to deduce from the most recent data of thermo-chemistry a complete theory of the utilisation of heat in furnaces of various kinds. The results he arrives at are very interesting. Taking, as an illustration, a Siemens furnace with double regeneration

* *Regenerativ-[illegible]* [illegible] Toldt. Leipzig: Arthur Felix. 1898.
† *La Chauffage* [illegible] Paris. Baudry & Co. 1898.



to protect the bottom from the scrap. The charge is rapidly finished; in fact, almost as soon as it is melted down. Both mild and harder steel may be made in this way. The pig iron contains a little silicon and a little phosphorus. Iron or steel scrap may be employed as long as it does not contain much sulphur, though it may contain phosphorus. In fact, it may be cold-short, but not red-short. The amount of metal made containing both sulphur and phosphorus is very small, so that scrap of that nature is not to be feared. Scrap from basic steel works is extensively used, and also scrap from the puddling furnace; and it is even proposed to manufacture the scrap regularly, as attention need only be directed to the removal of silicon, sulphur, and cinder. In America the rotary-furnace is used, and at Witkowitz small acid converters are employed, and the molten metal run direct into the open-hearths, which give six or seven heats in twenty-four hours. Impurities are removed by oxidation, and recarburising is done with ferro-manganese or with carbon. Poling is sometimes resorted to to accelerate mixing. To get rid of dissolved oxide, the metal is sometimes tapped into an acid-lined ladle, to which the ferro-manganese is added, and allowed to stand before casting. Ingots are generally cast from below in groups, and are often rolled without cogging or hammering, in which case some manipulation in the rolls is required to obtain fairly square plates. Generally only the mildest qualities of steel are made by this process.

Zaykowski * states that he experienced at first considerable difficulty in making satisfactory open-hearth steel from a white charcoal pig iron containing—

Carbon.	Phosphorus.	Silicon.	Manganese.
3·0	0·2 to 0·3	0·2 to 0·6	0·2 to 0·5

He finally succeeded, by using a charge consisting of 50 per cent. of this metal and 50 per cent. of scrap; but owing to the low percentage of manganese, difficulties were experienced until the workmen had learnt to tell the degree of hardness of the metal forming the bath, by the nature of the sparks observed. He agrees with Poech that a proper slag—one that is no mere mixture of lime and slag—is the needful requirement for the production of a good steel. An addition of spiegeleisen quiets the bath more rapidly and better than a corresponding addition of ferro-manganese; and similarly silicon-spiegeleisen is preferable to siliceous pig iron. Silicon must most distinctly be added to the bath only in a molten form, as it otherwise leads to a partial

* *Stahl und Eisen*, vol. xviii. p. 810.

[redacted]

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treatment than similar metal which has been recarburised and deoxidised with ferro-manganese alone.

J. Magery * traces the development of the appliances employed for the rolling of basic steel.

F. N. Speller † discusses the modern basic open-hearth process.

Discussions on the relative values of acid and basic open-hearth steel have been published.‡ [illegible]

The Bertrand-Thiel Open-Hearth Process.—According to J. [illegible] [illegible] of [illegible] of [illegible] of the [illegible] of [illegible] that [illegible] of [illegible]

[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	
[illegible]	[illegible]	

[illegible] furnace to [illegible] capacity of [illegible] and ore [illegible] melt the [illegible]

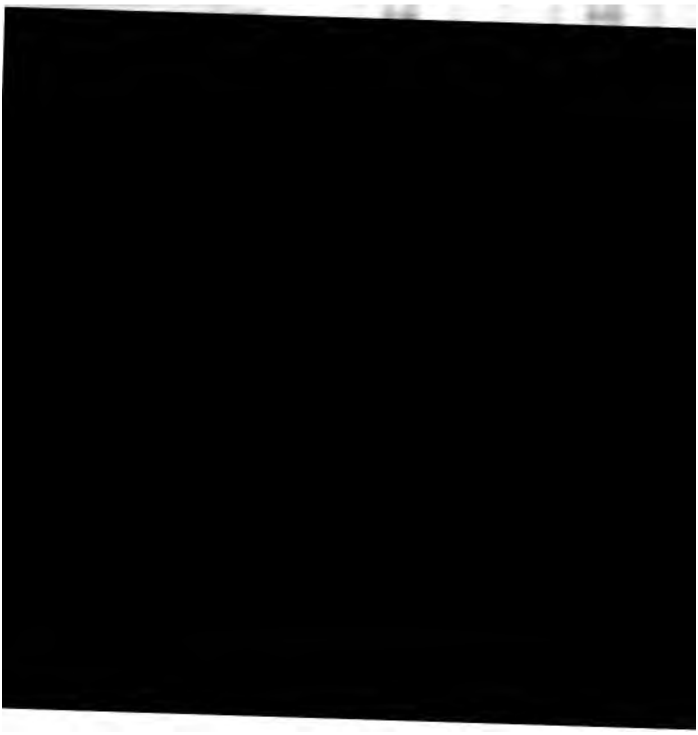
* [illegible]

† [illegible] Toronto, [illegible]

‡ [illegible] April 21, [illegible]

§ [illegible] Meeting, [illegible]

‖ [illegible]



charges have been from [illegible] tons, [illegible] tons of which [illegible] charged in the primary and the balance in the finishing furnace. These charges have as a rule consisted of about [illegible] per cent of pig iron and [illegible] per cent of steel scrap. The pig iron contains about [illegible] per cent of [illegible] and [illegible] per cent of silicon. The [illegible] has been [illegible] per week, averaging a little over [illegible] tons per [illegible] per week. The finishing furnace has generally [illegible] [illegible]

Molten Metal Direct from the Blast-Furnace.—The plant shou
ts of one primary and one finishing furnace. The latter should
ore than one-third larger than the former, and furnaces of t
acity will answer. From 60 to 80 per cent. of the charge shou
ed into the primary furnace in the shape of molten blast-furna
n, and the balance into the finishing furnace. This latter port
be charged cold, and may be either pig iron or scrap, or both,
be most convenient. The product will be eight to ten heats
of a weight determined by the size of the finishing furnace.

Molten Metal and Scrap.—In case the amount of scrap which
disposed of, or is economically available, amounts to more th
40 per cent., the plant should consist of one primary and
shing furnaces. This is on account of the time required to
scrap in the finishing furnace. The liquid metal and a little s
will be charged into the primary furnace, and the balance of
ap should be charged into the finishing furnace. If necessar
vent excessive oxidation of this scrap a little pig iron can
arged with it, or carbon can be added in the shape of coke
product will be ten to eleven heats per day, of a weight d
ined by the size of the finishing furnace.

These modifications of the plant and process cover most of the

ordinary repair, the furnace was charged March 30, 1897, and ran until August 21 of the same year, turning out 319 heats, when the checkers were taken out and replaced. No other repairs of any kind were made upon any part of the furnace. On August 26 the furnace was again charged, and ran until May 12, 1898, making 622 heats. This furnace, therefore, with absolutely no repairs save one change of checkers, turned out 941 heats, representing 17,666 tons of ingots, averaged 17 heats per week for the entire run, and 19 heats for twelve successive weeks during the run. The lowest number of heats made in any one week was 14 and the highest 20. No. 4 basic furnace (20 tons capacity) also made a creditable showing lately by turning out in one run 408 heats, representing 8344 tons of ingots, and averaging 15·7 heats per week. As this furnace was originally acid, and practically no change save that of the hearth was made when the basic process was adopted, the run is all the more remarkable. Limitation as to space prevents the adoption of slag-chambers and other improvements which are common to more modern furnaces, and handicapped on this account, these runs on producer gas furnaces are considered worthy of record.

The Schönwälder Furnace.—According to [illegible],* a Schönwälder furnace at the Zenica Works, Bosnia, is of [illegible]-ton capacity, and basic lined. Its use has given much satisfaction. After reconstruction the furnace stood 560 charges without the least stoppage, except the usual slight fettling, and it was estimated that the furnace would with certainty stand another 700 charges before any important repairs would be required.

Analysis of Austrian Steel.—[illegible]

	Per Cent.
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]

* [illegible]

[illegible]

[redacted]

[illegible]

[redacted]

J. Thieme,* discussing the open-hearth process in Southern Russia, refers to the use of molten ore, charged in quantities up to 25 per cent. of the pig iron charged. The duration of the charge has by this means been reduced from twelve hours to six hours, and the cost of the metric ton of ingots from £7 to £5, 7s. The process is as follows: The ore is first fused on the furnace hearth. In the case referred to it consists of Karnowatha ore containing—

Ferric Oxide.	Silica.	Alumina.
87·32	7·79	2·87

To this ore 17·6 per cent. of dolomite, or 40 per cent. of limestone, is added, the relative quantities required being first found by assay. The ore fuses readily, a temperature between 500° and 600° C. being adequate for this purpose. When this ore mixture is molten, the pig iron is run in in a molten form direct from the furnace. A violent reaction ensues, the mass taking up four times its original volume. This necessitated larger furnaces being used than those that had been formerly employed. To save time the Alexandrovski Works have projected the use of a small furnace specially for the fusion of the ore. The open-hearth used has a chrome iron ore bottom, the spaces between the lumps being filled in with crushed iron ore and thick milk of lime. The yield by this process at the Alexandrovski Works is stated to be as follows:—

	Per Cent.	Per Cent.	Per Cent.
Good material	80·22	73·83	76·61
Other kinds	7·10	9·67	8·71
Loss	12·68	16·50	14·68

This process has also been introduced at the Bogoslowski Works in the Ural. Here the ore contains—

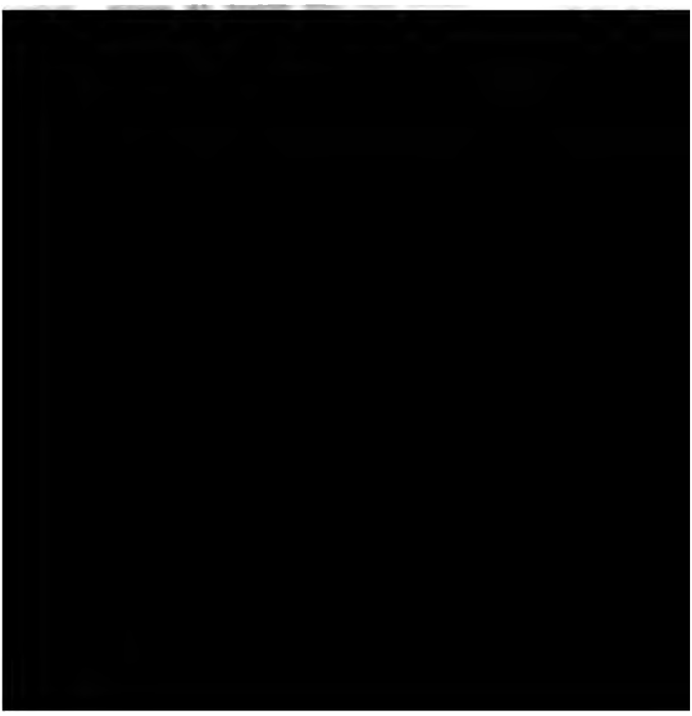
Ferric Oxide.	Silica.	Alumina.	Lime.
85·93	7·80	2·07	0·15

In view of the silica contents, 40 per cent. of limestone is added. Using cold pig iron the reaction is much less violent, and smaller furnaces are consequently adequate in size. This process was introduced at the last-named works owing to the absence of adequate scrap.

Open-Hearth Steel Manufacture in America.—In some notes on American iron and steel practice, A. P. Head † gives the following

* *Stahl und Eisen*, vol. xviii. p. 714.

† Paper read before the South Staffordshire Institute of Iron and Steel Works Managers, March 1898.



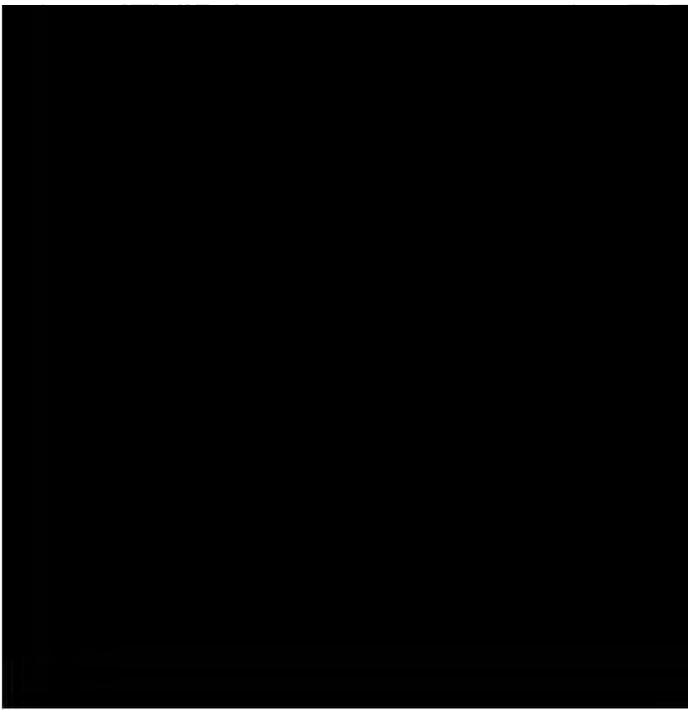
and elevation of the works together with other illustrations are given.*

Ten out of the twenty 45-ton furnaces at the Homestead Works have been completed, and of this plant a plan, elevation, and some views have recently been published.† The arrangement of this first half of the works consists of what are practically two separate and independent groups of five furnaces each, housed in one building, each group being disposed on either side of the central line of the main building. The furnaces are in two lines, with the casting side towards the centre of the main building. The space between the two is covered by two groups of overhead travelling cranes. The furnaces themselves and the charging floor, which are in the lean-to, are covered by a 40-ton crane and a 15-ton crane, the former to be used for handling a ladle for conveying molten metal from a metal mixer at the end of the building. The air and gas chambers are in front of the furnaces, and are of exceptionally ample dimensions. Although they are now using natural gas, the furnaces are designed so that producer gas may be used. The chambers are 22 feet long, inside measurement, and 14 feet 2 inches high to the top of the arch, the gas chambers being 6 feet and the air chambers 10 feet wide. The latter, therefore, have a cubic contents of 65 cubic feet per ton of charge. The present natural gas supply comes through a 20-inch main with a 6-inch branch to each furnace. The hearths of the furnaces are 28 by $13\frac{2}{3}$ feet, built up of one course each of fire-brick, chrome ore, and magnetic brick, covered with loose magnetite. The furnaces have three charging-doors and a small door at each end. In front of each furnace is a ladle pit. The ladles are 9 feet 2 inches in diameter in the shell and 7 feet 3 inches deep. They are handled for each line of five furnaces by two 75-ton Morgan electric travelling cranes, with a span of $37\frac{2}{3}$ feet and a hoisting speed of 12 feet. A third will suffice when the second half of the plant is built. Special devices prevent the ladle swinging or twisting. A subsidiary 25-ton crane runs on the lower flanges of the girders which carry the large cranes.

The system of casting on trucks has been adopted. Along the centre line of the main building on each side is a pouring track, and there are two double pouring platforms, provided with the mechanism for casting on either side. This consists of a pusher operated by a hydraulic cylinder with 14-foot stroke and 8-inch diameter, with mechanism for moving upward into position for engaging the dog which moves

* *Engineering News*, vol. xl. pp. 194-197, with plate.

† *Iron Age*, June 30, 1898, pp. 12-14, with plate.



III.—*THE BESSEMER PROCESS.*

Thermo-Chemistry of the Bessemer Process.—Professor W. N. Hartley,* in a series of Cantor lectures, deals with the thermo-chemistry of the Bessemer process. The history of the process is first shortly given, and then various forms of converters are described and the method of working discussed. The forms dealt with are the fixed converters, including the Swedish, Clapp-Griffith, Witherow-Clapp-Griffith and Hatton types, and the movable converters, including those of Holley, Thomas-Gilchrist, Walrand-Delattre, Robert, Davy, Tropenas, and Walrand-Legénisel. The thermo-chemistry is then investigated in detail, the explanation of the terms used being fully given. In this section of the subject, the lines previously followed by the author and by H. Ponthière † are followed, and in all material points the equations and conclusions of the latter are sustained, though some corrections are made. Both the acid and the basic process are investigated and compared. The third section deals with the investigations of the spectra of the Bessemer flame. The apparatus used is described, and the characteristics of the flame and its spectra at different periods of the blow are explained. Reference is made in this connection to the curves showing the elimination of the various elements and to the researches of prior authorities. These three lectures contain a succinct *résumé* of the whole subject in which the author has been so extensively concerned.

The Tropenas Steel Process.—Thomas Powell and Alexander Tropenas ‡ ascribe the failure of steel processes based on the use of small converters to their deficiencies as regards regularity of working, and to the lack of regularity and absolute control of the quality of steel.

The first Tropenas converter, of a capacity of about 800 lbs., was erected in 1891–92 in the works of Edgar Allen & Co., Sheffield, England. The trials made with this experimental vessel were so satisfactory that this firm have now three 2-ton converters, with which all their castings are exclusively made. There are now fifteen other concerns, of which a list is given, employing over thirty of these converters, ranging from 1 to 2 tons in capacity. In all these works the

* *Journal of the Society of Arts*, vol. xlvi. pp. 705, 721, 733, 760.

† *Journal of the Iron and Steel Institute*, 1897, No. II. pp. 96–114.

‡ *Journal of the American Foundrymen's Association*, vol. v, pp. 118–141, with illustrations; *Industries and Iron*, vol. xxv. pp. 28–29.

[illegible] have been used for manufacturing steel castings, and some ty[illegible] have been made. All the firms produce castings for their own [illegible] Governments and for prominent railways. They had no diffic[illegible] fulfilling the requirements called for in the specifications.

The mantle of the converter is so arranged that the metallic [illegible] a much greater depth or thickness than in all the other fo[illegible] is conical for small charges and cylindrical for large sizes. T[illegible] [illegible] rows [illegible] entirely independent of each other, being supp[illegible] through separate valves from the air main. The lower row cons[illegible] set of horizontal tuyeres, varying in diameter from 1½ to 2 in[illegible] according to the size of the converter, and opening into the conv[illegible] high enough to be always above the surface of the metallic bath. [illegible] upper wind box a second row of tuyeres is placed 8 to 1[illegible] above the lower row. They are flattened, and their free secti[illegible] equal to about three-quarters of that of the lower tuyeres.

When the melted pig iron has been run into the converter, the [illegible] [illegible] up to such a moment as to bring the lower tuyeres [illegible] metallic bath, but always above it. The air-valve of the top [illegible] [illegible] closed. Then blowing is commenced in this position with [illegible] bottom tuyeres. When the operation is well under way th[illegible] valve is opened so as to admit through the tuyeres a supplem[illegible]

metal, [illegible], and air takes place. The steel produced by this process [illegible] purer and contains [illegible] gas in [illegible]. [illegible] being particularly [illegible] is no [illegible] of steel [illegible] the [illegible] of metal [illegible] compensates [illegible] the loss [illegible] per cent [illegible] resulting from [illegible] upon the surface.

[illegible] increasing [illegible] more fluid. The [illegible] better [illegible]. [illegible] bottom of the ladle.

[illegible]

[redacted]

[redacted]

"In the art of mixing molten metal to secure uniformity of the same in its constituent parts preparatory to further treatment, the process of introducing into a mixing-receptacle successive portions of molten metal ununiform in their non-metallic constituents (sulphur, silicon, &c.), removing portions only of the composite molten contents of the receptacle without entirely draining or emptying the same, and successively replenishing the receptacle with fresh ununiform additions, substantially as and for the purposes described."

Cost of Steel.—A series of articles dealing with the cost and conditions of producing iron and steel in Great Britain have appeared. Numerous detailed statements of cost are given.*

The History of Bessemer Steel.—E. Riley † gives an account of his early connection with the Bessemer process.

Bessemer Steel Manufacture in the United States.—In some notes on American iron and steel practice, A. P. Head ‡ states that owing to the great improvement in mechanical appliances which has been, and is still being made in the melting house, the day may not be far distant when the Bessemer process will be superseded in favour of the open-hearth basic furnaces.

The usual equipment of an American Bessemer converting-house comprises a pair of 10-ton converters, with four 10-ton cupolas, and every appliance for quickly disposing of the output. The average time for filling, blowing, and pouring is twenty minutes, giving an output from a pair of converters of 40,000 tons of ingots per month.

On December 31st, the record for quick blowing was broken at the Duquesne Works, when two converters made 204 heats in twenty-four hours, producing 1928 tons of ingots, with an average of fourteen minutes per blow. The plant at the Edgar Thomson Steelworks is well arranged for the quick disposal of large outputs, and an illustrated description of it is given.

At the Duquesne Steelworks, the metallic loss between pig iron and ingot is 6½ per cent., but the dust, rich in iron, which is collected from the converter-house floor, and returned to the blast-furnaces, reduces this [illegible] per cent., leaving a net loss of 3½ per cent. At the

* [illegible] pp. 60, 64, 95.
† [illegible]
‡ [illegible] South Staffordshire Institute of Iron and Steel Works [illegible]

FURTHER TREATMENT OF IRON AND STEEL.

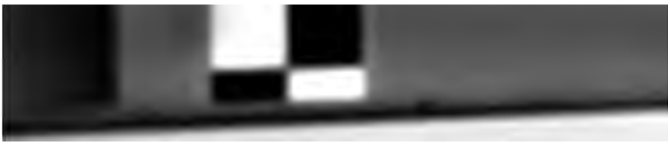
Steel Castings.—S. Kern * describes the manufacture of steel castings for ship-building purposes in Russia. The melting furnace is fired with coke, and gives about 3 cwt. daily in four crucibles per heat. All castings are annealed in charcoal. The moulding sand consists of about 90 per cent. of fine quartz sand, and 10 per cent. of the best fire-clay mixed with a small quantity of sawdust and rye flour. As a wash for mouldings, malt boiled with water is used. Ferro-silicon-manganese containing 10 per cent. of silicon and 80 per cent. of manganese is preferred as an addition. Ferro-aluminium, with 14 per cent. of aluminum, is also used. The castings as a rule contain about—

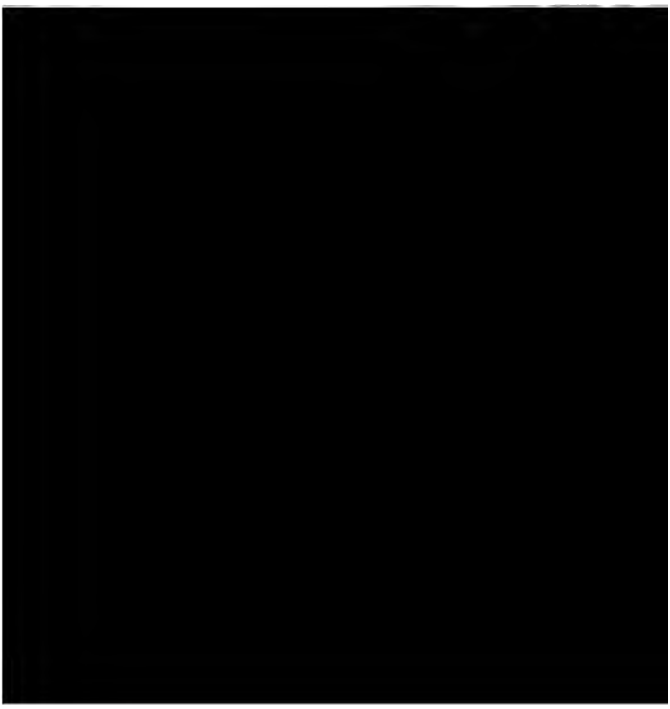
C.	Mn.	Si.	S.	P.
0·40	0·42	0·35	0·02	0·04

and give an elastic limit of 21 tons per square inch, tensile strength of 45 tons, and an elongation of 8 to 10 per cent. on 4 inches. For boiler-work and water-tight castings, carbon is increased to 0·60 per cent.

The crucible charge for ordinary castings contains: Steel plate roundings, 50 lbs.; steel plate shearings, 10 lbs.; puddled iron, 20 lbs. When the charge is melted, which results after some five hours, an addition is made, consisting of silico-manganese, 0·75 lb.; ferro-aluminium, 0·15 lb.; ferro-manganese (containing 80 per cent. of manganese), 0·10 lb. In all, the addition weighs 1 lb., and is introduced into each crucible by means of a funnel, and remains there for twenty minutes before casting. The crucible charge for water-tight castings consists of ship-plate roundings, 55 lbs.; ship-plate shearings, 10 lbs.; puddled iron, 12 lbs.; refined best cast iron, 3 lbs. The following is the addition for such a steel: Silico-manganese, 0·70 lb.; ferro-aluminium, 0·25 lb.; ferro-manganese (containing 80 per cent. of manganese), 0·15 lb. This

* *Chemical News*, vol. lxxvii. pp. 86–87.



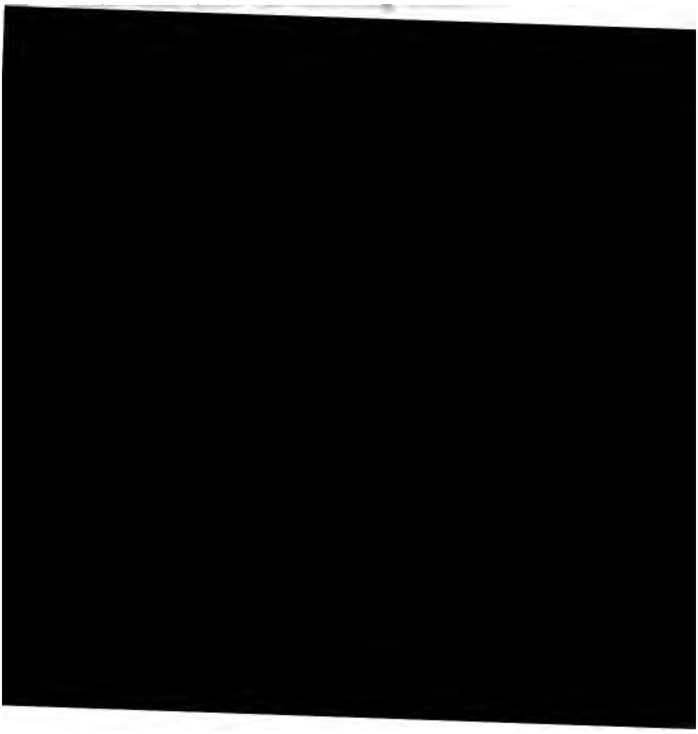


use in the manufacture of those machine parts that can be only made with much difficulty by ordinary welding methods. Tests of the metal have shown an elongation of 11·6 to 10·6 per cent., with a reduction of area of 30 to 32 per cent., and a maximum tensile strength of 49,923 lbs. per square inch. It is said to be easy to work, and to be capable of being hammered and bent in the cold without cracking.

Weights of Steel Bars.—Under the title of "Weights of Steel Bars," Frank Barker * has published a very useful and handy book for the use of iron and steel manufacturers, merchants, tilters, rollers, mill-managers, and all those engaged in the working of or dealing in iron and steel. The tables are very complete, and arranged so that the weight of a bar any size or length can be ascertained at a glance, in squares, octagons, and rounds, from $\frac{3}{16}$ inch up to 12 inches diameter, and in flats from $\frac{3}{16}$ by $\frac{3}{16}$ inch up to 12 inches by 3 inches. The weights of hexagons, ovals, and three-squares are given, and also weights of sheets. The book also contains tables for the conversion of French weights and measures into their English equivalents, English gauges into decimals and fractions of inches, together with other useful information that the foreman in iron and steel works requires.

Case-Hardening Ingots.—A system of case-hardening ingots has been devised by Emile Demenge † and put in practice at the Pamiers Steelworks. It consists in directly carburising one face of the ingot at the time of casting, by lining one of the vertical sides of the mould with carburising matter, and preventing this carburisation from penetrating too deeply into the inside of the ingot by cooling the vertical side of the mould opposite the carburising side. The case-hardened surface is rather rough; but all irregularity disappears in forging, which may be effected without special precaution and at a comparatively low temperature, by the press rather than the steam-hammer. Ingots of ½ to 3 tons are said to have been cast in this manner; and a 3-ton ingot, 16 inches thick, reduced by forging and rolling to one-fourth that thickness, was found to contain from 1·78 to 1·5 per cent. of carbon between its hard surface and a depth of 3·16 inches; from 0·60 to 0·40 per cent. between 1 and 2 inches from the surface, and from 0·35 to 0·15 per cent. between $3\frac{9}{16}$ and 4 inches.

* "Weights of Steel Bars," 2nd edition. Sheffield, [illegible].
† *Industries and Iron*, vol. xxv., p. 352.



2 miles on the tram-lines in Berlin, the ends of the different rails have been joined solidly together by casting iron between the ends so as to make the rails into one piece. Consequently over the whole length there is practically only one single long rail. This is found to work satisfactorily.

Stress is laid by Vietor * on the urgent necessity for strengthening the permanent way of German railways. He deals generally with the subject touching on the rails in use and their fastenings, and on the spaces left between the rails, and generally reviews the whole question.

Steel Sleepers.—C. Renson † has prepared a report on the use of metal sleepers on the Liége Limberg line of the Netherlands state railway. Various forms, of which illustrations are given, have been used since 1865, and the results as regards wear are discussed. Other details on the same subject from the Gothard railway have also appeared.‡

Waggons.—A number of different forms of trucks or bogies for waggons built of steel are described.§

Fully dimensioned illustrations have appeared ‖ of a 44-ton pressed steel coal waggon of American design. The weight of the waggon is 40,100 lbs., and the carrying capacity 44 tons, or two and one-half times its weight. The waggon is 36 feet 6 inches long over end sills, and 9 feet 6 inches wide over stakes, while inside it is 34 feet long by 8 feet 4 inches wide. The underframe, excepting the centre sills, is entirely of pressed shapes.

Large Boiler-Plates.—Two of the largest steel boiler-plates ever rolled in America were recently turned out at the South Chicago Works of the Illinois Steel Company. The plates were of open-hearth steel, and each is intended for the shell surrounding the fire-box in two locomotives now being built for the Cleveland, Cincinnati, Chicago, and St. Louis Railroad. Each of the finished plates was 124 inches wide, and 220 inches long on one edge and 237 inches on the other; the sheets before the shearing were 128 inches by 360 inches for one and 130½ inches by 375 inches for the other, while the ingots

* *Stahl und Eisen*, vol. xviii. pp. 689–696.

† Bulletin of the International Railway Congress, 1897, through the *Engineering News*, vol. xl. pp. 118–119; *Stahl und Eisen*, vol. xviii. pp. 837–846.

‡ *Engineering News*, vol. xxxix. pp. 227–228.

§ *Ibid*, vol. xl. pp. 164–166.

‖ *Iron and Coal Trades Review*, vol. lvii. pp. 305–306.

[redacted]

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Werth,* of the Denain and Anzin Works, uses those alloys containing nickel or cobalt and manganese, which have the property of assuming a hard state when air-cooled from a bright red temperature, although they remain soft if cooled from lower temperatures. The metal used is open-hearth steel, free from sulphur and phosphorus, and containing 5 to 15 per cent. of nickel or cobalt, and 2 to 12 per cent. of manganese. In its soft state such steel has a tensile strength of 110,000 to 140,000 lbs. per square inch. One side of the plate is slowly heated in a furnace to a bright red heat, while the back is maintained at 800° to 900° F. Or the face to be hardened is immersed in red-hot lead. When ready, the plate is removed from the furnace, and cooled at the back until the front face is at a temperature of 800° to 900° F., and then no further attention is required.

T. Ulke † gives an account of the manufacture of nickel steel armour in the United States.

Armour-Piercing Projectiles.—J. Castner ‡ observes that the war between Spain and the United States caused the latter to call on the United States steelworks to provide armour-piercing projectiles. This request led to an improvement, which the author proceeds to describe. It is required of such projectiles that they shall penetrate armour-plates without breaking up, and subsequently burst within the vessel and behind the armour-plate, so as to cause as much destruction as possible. It has not, however, hitherto been found possible, the author observes, either by the Krupp Works or by others, to produce projectiles which fully satisfy these requirements. As a rule the explosion takes place while the projectile is in the armour-plate itself, the shot showing a marked tendency to break up after impact. The greater part of the work of penetration is performed by the point of the shell and the conical portion behind it, the cylindrical portion merely increasing the effect. The first-mentioned portion must therefore be harder than the cylindrical portion need be, resistance to compressive force being the main thing required of that part of the shell. On striking the armour-plate the cylindrical portion, being subject to compression, increases in diameter, and the hole made by the conical part is not large enough to allow the body of the shell to pass. This is therefore obliged to take part in the work of penetra-

* *Engineering*, vol. lxv. p. 770.
† *Cassier's Magazine*, vol. xiv. pp. 34–47.
‡ *Stahl und Eisen*, vol. xviii. pp. 894–897, with two illustrations.

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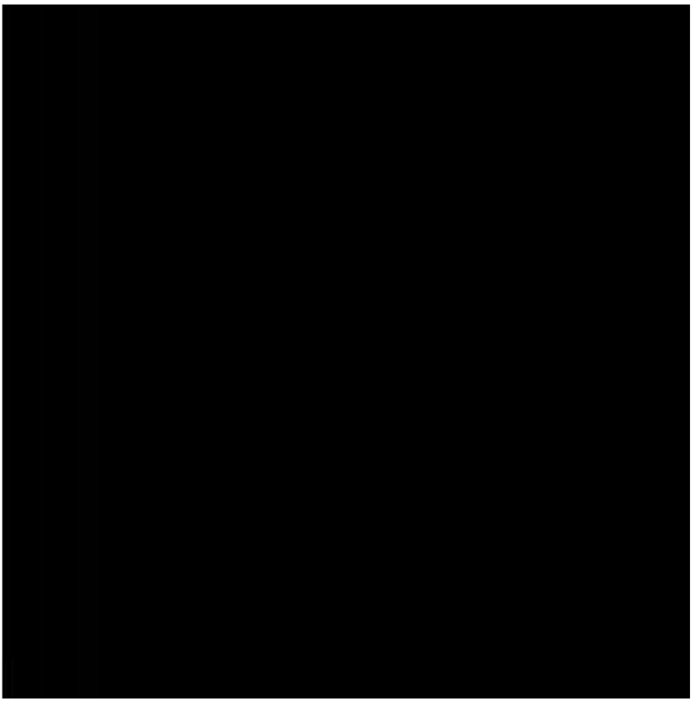


vertically in the bath, so that freer circulation of the acid is obtained, and the liquid may be of less strength than usual.

H. Souther * criticises the so-called McCool process of manufacturing tubes, and objects to the term seamless, which has been applied to it, as the tubes are made by cold drawing welded tubes.

Wire Manufacture.—S. [illegible] points out that the production of wire [illegible] States was [illegible] tons in [illegible] [illegible] kegs were produced in these two years. [illegible] and [illegible] wire. [illegible]

Manufacture of Pipes. [illegible]

[redacted]

[redacted]

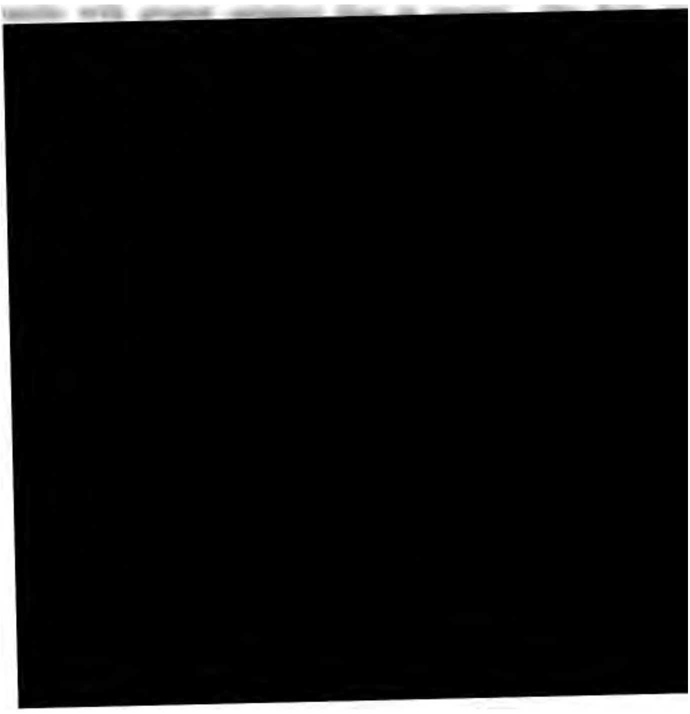
has also been employed, but when the plate is simply used as the anode in an acid bath, it is liable to pitting. This is overcome by reversing the current periodically, and the process is quickened by heating the bath by steam coils. A false bottom in the tank is arranged to catch any scale that drops off, and is removed at intervals, or the scale may be removed continuously by circulating the liquid through a lead-lined box outside in which magnets are placed. Current generated by the plates during pickling has been utilised, and attempts have been made to remove the scale by electro-magnets after it is loosened by pickling.

Protective Metallic Coatings for Iron and Steel.—S. Cowper-Coles * deals with the various methods of coating iron and steel with protective metallic coatings. Galvanising or coating with zinc both by the hot method and by electrolytic methods are described and discussed at considerable length, but the use of other metals such as lead, &c., is also referred to in some detail.

Illustrations are given † of the Wyndham Thomas tinning machine and of the Lewis double tinning machine.

* Paper read before the Society of Engineers, 3rd October 1898, through *Industries and Iron*, vol. xxv. pp. 284, 304, &c.

† *Iron and Coal Trades Review*, vol. lvii. pp. 476, 552.



A. Greiner * has published an exhaustive memoir on the progress achieved in the knowledge of the internal structure of steel. His paper is illustrated by thirty-six micro-photographs.

Magnetic Properties.—E. Dumont † has determined the magnetic permeability for fields lying between 14 to 50 C.G.S. units, and for temperatures between 78° and 250° C. of reversible nickel steels containing from 27 to 44 per cent. of nickel. At a temperature of 20° C. all the alloys show similar changes of permeability, with variations in the magnetising field, rising slowly as the field is strengthened from 14 to 25 units, then rapidly increasing to a maximum in a field of 35 units, and slowly diminishing as the strength of field is increased. Under the same circumstances of temperature and strength of field the permeability increases with the higher percentage of nickel.

Professor J. A. Ewing ‡ describes a workshop instrument for making tests, in an easy and rapid fashion, of the magnetic permeability of cast and forged metal for dynamo magnets. The instrument is a magnetic balance of the traction type. The facing of the end of the bar is not required, the magnetic pull being exerted between the side of the turned bar and the convex surface of a magnet pole which it touches, and from which it is pulled away by an adjustable balance-weight on a lever.

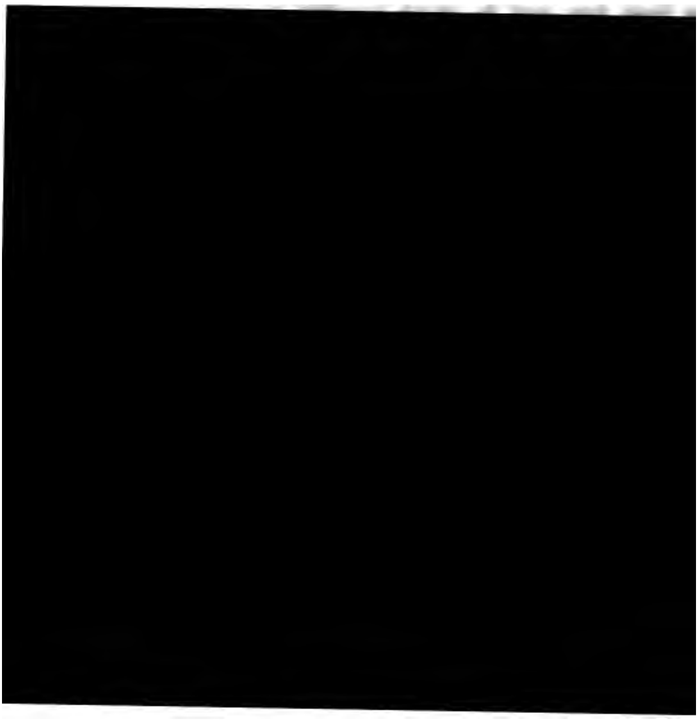
Yoshijiro Kato § has experimented on the time lag in the magnetisation of iron, following Ewing's method of using a magnetometer, and observing the creeping, but higher forces were used, and the wires were subjected to moderate loads. The results are given in tabular form and as curves, and the meaning of the phenomena is discussed.

K. Tsuruta ‖ discusses the thermo-electric effects of longitudinal stress in iron and gives the results of his experiments, which generally agree with those obtained by Ewing.

Professor J. A. Fleming has given a series of the Tyndall lectures at the Royal Institution, the subject chosen being recent researches in magnetism and diamagnetism.

E. Wilson ¶ gives in tabular form the results of determinations

* *Revue Universelle des Mines*, vol. xlii. pp. 145–171.
† *Comptes Rendus de l'Académie des Sciences*; *Industries and Iron*, vol. xxiv. p. 458.
‡ *Journal of the Institution of Electrical Engineers*, vol. xxvii. pp. 526–546.
§ *Journal of the College of Science, Imperial University of Japan*, vol. ix. pp. 295–370.
‖ *Ibid.* pp. 27–50.
¶ *Electrical Review*, vol. xlii. pp. 313–314.



A detailed account of this investigation has been published by the author* in Swedish.

The Hardening Power of Low Carbon Steel.—Professor H. M. Howe † has experimented upon the effect of quenching iron, steel, and other metals in frozen mercury and in frozen alcohol. The effect on a sample containing—

Carbon.	Phosphorus.	Sulphur.	Copper.
0·022	0·007	0·014	0·10

was to increase the elastic limit 157 per cent., the tenacity 54 per cent., and the elongation 95 per cent. An electrolytic iron containing 0·009 carbon also gained, but not to the same extent. The effect of quenching in melting mercury is greater than with frozen alcohol, probably due to its greater conductivity, though the alcohol is colder. It was also noticed that the transverse strength and elastic limit are benefited much more than the tensile strength. The hardness is also greatly increased. The author concludes that the results are out of proportion to the amount of carbon present. As mechanical treatment produces somewhat similar results, they might be ascribed to the stresses applied, but quenching copper and other metals give negative results, so the effects can only be ascribed to allotropy. A series of further tests is suggested.

Determining the Hardness of Cast Iron.—C. A. Bauer ‡ describes a method for determining the relative hardness of different samples of cast iron. A drill running at a uniform rate of speed and under a constant pressure is employed, and the number of revolutions that it takes after the drill is embedded to penetrate a further distance of half an inch is taken as indicating the hardness. Automatic counting appliances are used, and the number of revolutions in three trials on four test-bars are shown below :—

No. of Bar.	No. of Revolutions.		
I.	130	128	129
II.	150	149	149
III.	170	168	167
IV.	236	232	230

* *Om järnets kritiska längd- och temperaturförändringar*, Upsala. A copy has been presented by the author to the Institute library.

† *Metallographist*, vol. i. pp. 259-265.

‡ *Journal of the American Foundrymen's Association*, vol. v. pp. 64-69.

which the energy actually absorbed in breaking the test-bar can be measured. This is accomplished by using a hammer in the shape of a pendulum so arranged that it strikes a horizontal blow, breaking clear through the bar, and swinging freely up to the height due to the velocity after the impact. The test-piece, resting against the two vertical knife edges, is struck in the middle by the falling pendulum, and thus gives the ultimate resilience of the bar under transverse stress. A full description of the machine and illustrations are given, followed by a discussion of the various errors to be allowed for in the results, due to the friction of the machine, the inertia of the test-bar itself, &c. Formulas and tables are appended, and the following conclusions are reached:—1st, Definite values for the resilience of brittle materials may be obtained; 2nd, for tough materials, such as wrought iron, definite relative values for the resilience of metals of the same class may be obtained. Finally, attention is called to the value of a thorough knowledge of the resilience of materials used in structures, in designing work exposed to live load and shock. Iron and stone can replace wood with a greater assurance of safety than is now the case, and thus keep out useless material, which is generally a positive detriment to a structure.

An impact testing machine being designed for the Massachusetts Institute of Technology, to test axles, &c., is to have a form like a pile-driver, with a tup of 500 lbs., having a fall up to 8 feet. Another machine is to be built for repeated stresses in opposite directions up to 100,000 lbs.*

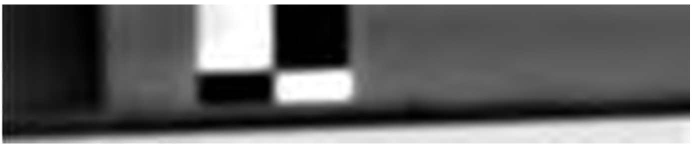
B. Kirsch† discusses the degree of accuracy obtainable with testing machines, and also that of the results of tensile tests generally. He refers to the various methods that have hitherto been employed in testing testing-machines to ascertain their accuracy, describing the Bauschinger, Föppl, Martens, and other methods, and, in particular, describes the method he himself adopts for this purpose, giving a series of test results. He shows that the error does not, on the average, exceed about 0·5 per cent., and it may be less than this. Such an error as this, the author thinks, is one with which, for practical purposes, one may well rest content.

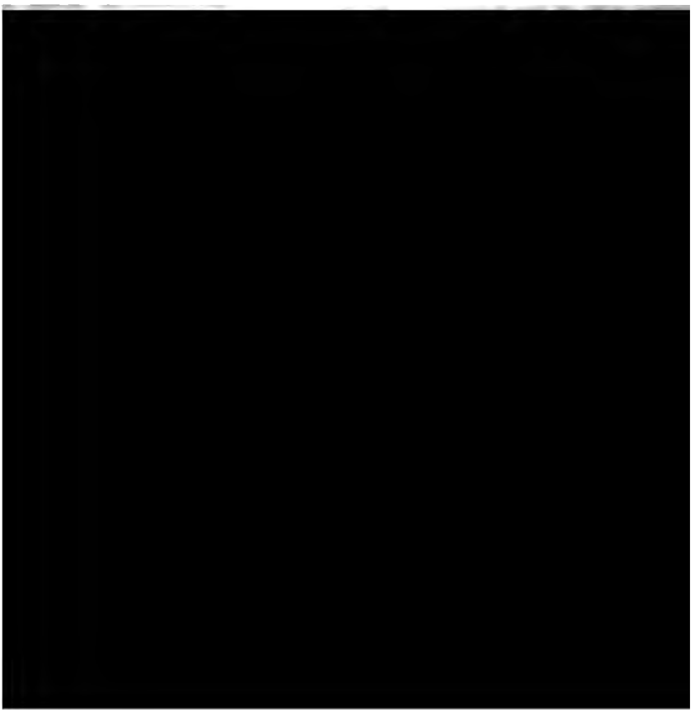
The Theory of Elasticity and Ultimate Strength.—Dr. Kirsch‡ deals with the theory of elasticity and ultimate strength,

* *Engineering News*, vol. xxxix. p. 216.

† *Stahl und Eisen*, vol. xviii. p. 557-562.

‡ *Zeitschrift des Vereines deutscher Ingenieure*, vol. xlii. pp. 797-807.





a long series of compression tests of wrought iron cylinders to determine the influence of the length and diameter, and the method of failure. Four series of specimens, 142 in number, were used. They had areas of ¼, ½, ¾, and 1 square inch respectively, and lengths ranging from 1 to 12 inches. Tensile tests of the material used showed—

	Ultimate Strength.	Elastic Limit.
	Lbs. per Sq. In.	Lbs. per Sq. In.
Series A and B	52,000	40,000
Series C and D	53,425	26,110

In the crushing tests the methods of failure were as follows:—

Series A: Area, 0·5 square inch; diameter, 0·798 inch; lengths, 4½ to 8 inches failed by bending; 3 to 4 inches by crushing and bulging; 2½ inches mostly by bulging; 1 to 2 inches by bulging.

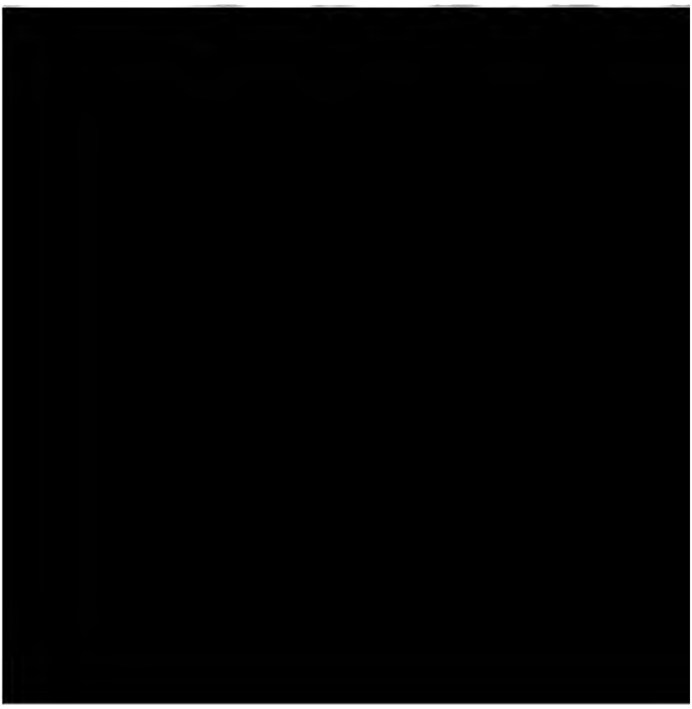
Series B: Area, 1 square inch; diameter, 1·128 inch; lengths, 6½ to 8 inches by bending; 5½ to 6 inches by bending with slight bulging; 4 to 5 inches by bending and bulging; 1 to 3½ inches by bulging.

Series C: Area, 0·75 square inch; diameter, 0·983 inch; lengths, 5½ to 12 inches by bending; 3½ to 5½ inches by bending and bulging; 3 inches mostly bulging; 1 to 2½ inches by bulging.

Series D: Area, 0·25 square inch; diameter, 0·564 inch; lengths, 3½ to 10 inches by bending; 2½ and 3½ inches crushing and bulging; 1½ and 2 inches by bulging.

The results of the tests are plotted, and are also given in tabular form. Some of the results for series C, in which the pieces had an area of 0·75 square inch, are as follows:—

Length. Inches.	Ratio Length to Diameter.	Yield-Point. Lbs. per Sq. In.	Maximum Stress per Sq. In. Original Area. Lbs.	Deflection at Maximum Stress. Inch.	Final Diameter. Inch.	Stress per Sq. In. of Final Area. Lbs.
12	12·19	30,305	31,980	0·36	0·996	31,982
9	9·16	28,450	29,600	0·27	1·001	26,150
6	6·22	30,030	36,450	0·40	1·023	33,390
3	3·21	31,500	62,900	1·00	1·19	42,200
2	2·20	32,200	132,000	0·81	1·34	61,300
1	1·21	31,720	148,700	0·55	1·41	70,700

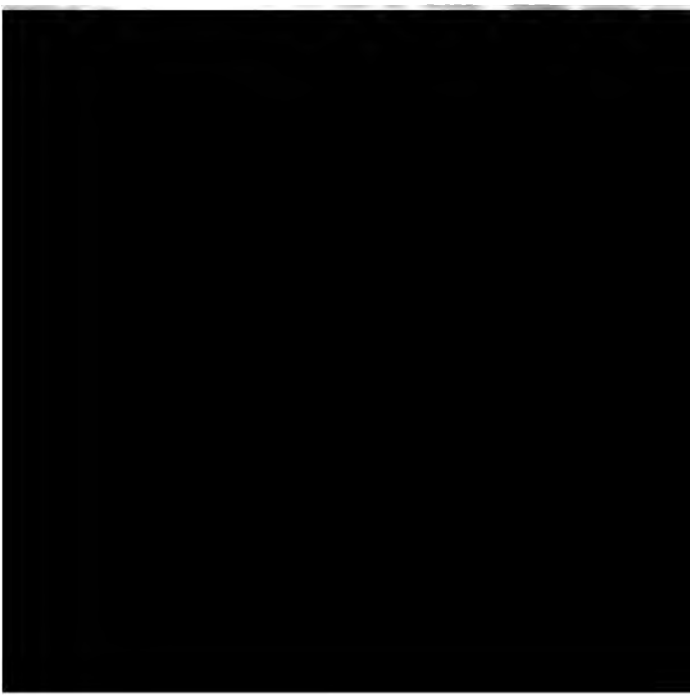


Diameter of Pipe. Inches.	Weight per Foot. Lbs.		Bursting Pressure. Lbs. per Sq. In.		Tensile Strength. Lbs. per Sq. In.	
	Iron.	Steel.	Iron.	Steel.	Iron.	Steel.
2	3·452	3·821	4,000	over 6,000	50,002	65,999
2	3·864	3·840	5,000	over 6,000	51,852	63,057
5⅝	10·003	9·824	1,400	2,750	54,311	82,325

Frictional tests showed but little advantage to either.

Fatigue of Metal in Forgings.—H. F. J. Porter * sums up his views of steel forgings as follows:—Although forgings can be made to fill a large variety of specifications, they can, in general, be divided into five classes, as follows: 1. Mild steel, annealed; 2. Medium hard steel, annealed; 3. Medium hard steel, oil-tempered; 4. Nickel steel, annealed; 5. Nickel steel, oil-tempered. Each of these classes is supposed to cover a series varying greatly in strength. Large shafts and similar forgings, crank, and crosshead pins should be made of fluid-compressed steel, and should be hydraulic forged, not hammered. Wherever practicable, an axial hole should be bored through shafts to ensure absence of any internal defects. If forgings are oil tempered, the hole can be made larger in diameter than if they are simply annealed, and where the hole is 7 inches in diameter and above they can be hollow forged on a mandrel. A hollow-forged, oil-tempered forging ensures the highest attainable qualities, and can be especially recommended where the maximum strength with the greatest lightness is desired. Where it is important that the quality specified should be obtained in the more important parts, physical tests of the forgings as delivered should be demanded. For such tests prolongations should be left on the end of forgings for the purpose of having test specimens cut from them after the forging and treatment have been completed. Such prolongations should receive no greater reduction than the forging at its largest part. The following table shows the average physical qualities that should be obtained in forgings made of the several grades of steel mentioned, the test specimens being 2 inches long between measuring points, and ½-inch in diameter, and cut from full-sized prolongations of the forgings after treatment:—

* *Journal of the Franklin Institute*, vol. cxlv. pp. 241–261, and 321–355.



periments are given in detail, and the experiments themselves described. It was found necessary to provide the metal with a protective mantle; and when this was done, but not otherwise, the results were much better than when wood was employed in the place of the metal. The ways in which iron and steel are now actually employed in building construction are further dealt with at considerable length, and with the aid of numerous illustrations.

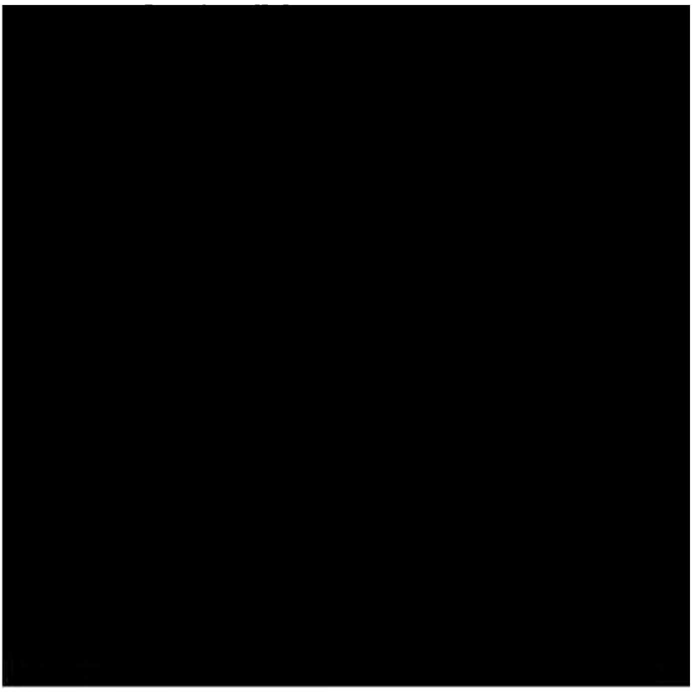
Tests of Iron Columns. — The Association of German Iron Foundries has arrived at the following conclusions:* (1) Vertically cast columns are no better than those cast horizontally; (2) determination of the thickness of the sides of such columns by drilling, and subjection to twice the crushing force they are to be called upon to subsequently support, are adequate tests; (3) they consider that while vertical casting has been shown to be of advantage for pipes, columns ought to be cast horizontally, and various reasons are given for this. Impurities too, it is pointed out, do not separate out in the same satisfactory way in the case of columns cast vertically as in the case of pipes cast in this manner.

The British Fire Prevention Committee† have published an account of the independent fire-tests made on unprotected columns at Brooklyn. The columns were heated in a brick chamber by gas, assisted by a naphtha spray, and loaded by hydraulic pressure. The temperature was determined by a pyrometer. Photographs of the columns after the test are reproduced with the log of each of the five trials. Two steel and three cast-iron columns were tested.

W. H. Burr‡ discusses the test of cast-iron columns recently made.§

Testing Material for Rolling Stock.—G. T. Glover‖ gives an account of the present requirements for rolling stock material in this country, and the manner in which the tests are carried out. Standard tests are not in use except for tires, axles, and springs for private owners' waggons; but it would be of advantage to have a standard length for tensile test-pieces, and also for bending-pieces. At the pre-

* *Stahl und Eisen*, vol. xviii., pp. [illegible].
† *Publication*, No. 11, London, [illegible].
‡ *School of Mines Quarterly*, vol. [illegible], pp. [illegible].
§ *Journal of the Iron and Steel Institute*, [illegible], No. I., p. [illegible].
‖ *Engineer*, vol. [illegible], pp. 1, 70, 130, 146, [illegible].



Wear of Tramway Rails.—A. J. Moxam * gives the results of some experiments lasting over three years on the wear of tramway rails. The wear in these rails is partly due to the grinding action of the dirt, and this factor does not occur with railway rails. Three rails were tested; their composition and amount of wear was as follows:—

Carbon	0·280	0·590	0·570
Silicon	0·026	0·056	0·234
Phosphorus	0·106	0·097	0·050
Sulphur	0·066	0·059	0·078
Manganese	0·790	0·830	0·980
Monthly wear, inch	0·0017	0·0012	0·0007

It would seem that hard rails are preferable, and that the hardness should be attained by increasing the carbon. At the same time, it is pointed out that rails have to be renewed on account of the destruction at the joints long before the rails are worn out.

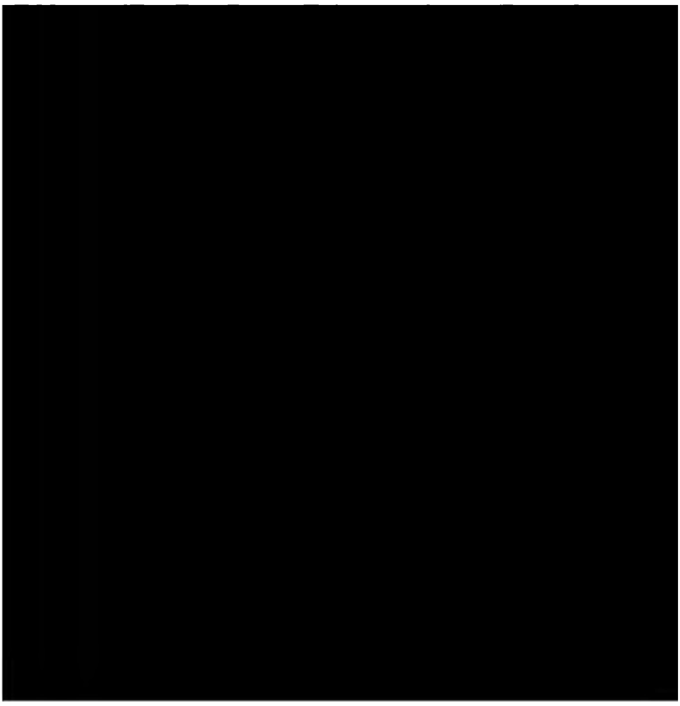
Basic Steel for Rails.—The use of basic steel for rails is discussed by Fischer,† who also deals with its application to other uses. In connection with the question of the quality of the material he lays special stress on etching tests. These afford an accurate and rapid idea of the homogeneity of the material under inspection. Now-a-days it is quite possible to produce a perfectly trustworthy steel having an ultimate tensile strength of 41¾ tons per square inch, and it is even probable that such steel will soon be used for rail construction with an ultimate strength of 44½ tons per square inch. The author deals in some detail with tramway construction, and the rails used for this purpose. Whether for such purposes the method of filling up the spaces between the ends of the rails will endure must, he observes, await the results obtained in practice, but it is not, however, capable of utilisation in connection with ordinary railways.

Cast-Iron Wheels.—S. P. Bush ‡ states that there is no difficulty in producing wheels which will stand the thermal test, and the only difficulty in uniformly applying the test is that of ensuring that the molten metal poured around the wheel is at the same temperature in all cases. Analyses of the metal from wheels which did and which

* Paper read before the New York State Street Railroad Association, September 1898, through the *Iron Age*, vol. lxii. No. 14, p. 4.

† *Zeitschrift des Vereines deutscher Ingenieure*, vol. xlii. p. 760.

‡ *Proceedings of the Master Car-Builders' Association*, vol. xxxii. pp. 182-188.



caps are given. In appendices are given lists of the numerous United States experiments on face-hardened armour and on capped projectiles.

The first armour-plate made according to Krupp's process at the Carnegie Steel Company's works was tested on July 13 * at Indian Head. The plate was 6 inches in thickness, and was attacked by four 6-inch armour-piercing shells. Striking velocities were 2021, 2237, 2350, and 1984 foot-seconds. The third shot penetrated the plate, and remained lodged in the backing. The fourth shot was capped, and passed through the plate and backing. A similar plate nearly 12 inches in thickness was tested on September 12 † by three shots from a 12-inch gun. The velocities were 1833, 2022, and 1720 foot-seconds. The penetration of the first and third shots were 8½ and 5 inches respectively, whilst the second shot passed through the plate.

A Krupp process plate made by John Brown & Co., Atlas Works, was tested on July 21 by three blows of 12-inch Holtzer armour-piercing shot, each weighing 714 lb., striking with velocities of 1852, 1886, and 1869 foot-seconds. The dimensions of the plate are 10 feet by 7 feet by $10\frac{3}{4}$ inches, and its weight about 15 tons. None of the shots perforated the plate, of which photographs are given,‡ to show the scaling of the surface and the small cracks produced in the back.

On August 17 two 4-inch Brown steel armour-plates, each 4 feet by 4 feet by 4 inches, were each tested by the attack of three 5-inch Palliser shot, weighing 50 lbs., striking with the successive velocities of [illegible], 1760, and 1780 foot-seconds. The plates were both uncemented or face-treated. One was slightly harder than the other. This showed some slight superficial cracks after attack, the other showed none, but the indentations in the latter were appreciably deeper than in the former.

A short sketch of the connection of the Gruson Works with armour manufacture is given, with illustrations of a number of tested plates with a list of their trials. The armour-plate plant is also described at length with many illustrations.§

A series of articles is appearing‖ on the production and supply of

[illegible]

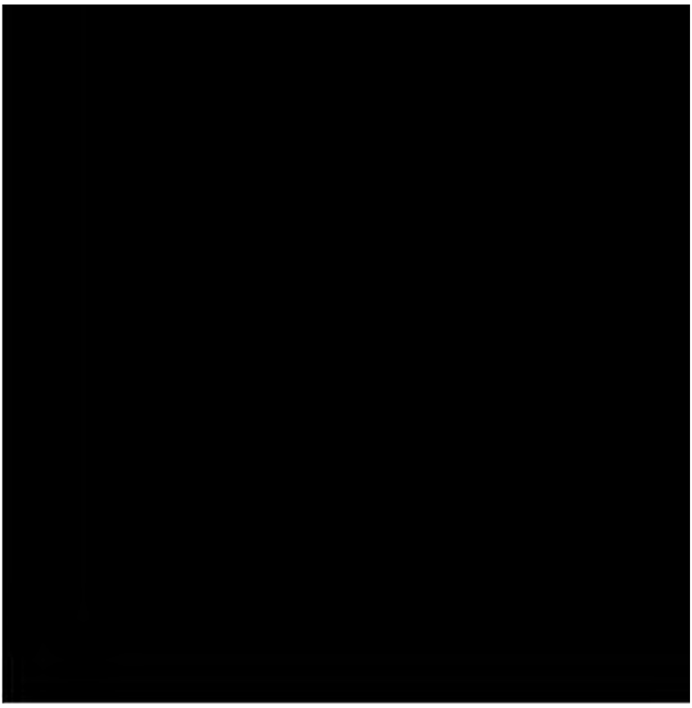
Nickel-Chrome and Silicon Steels.—A. Abraham * describes a large number of experiments made with certain special steels. These include steels containing 25 per cent. of nickel and 2 to 3 of chromium, and a steel with 1·5 per cent. of silicon. Another steel specially studied contained 12 per cent. of nickel and from 1 to 1·5 per cent. of chromium. This latter showed itself, the author observes, to be possessed of remarkable mechanical properties. The author has considered generally the question of the use of nickel and chromium in steel.

Dealing, in the first place, with the question of the use of nickel and chromium in steel intended for armour-plates, he observes that chromium was the first metal that was thought of as a suitable addition to steels, such as those required for armour-plates. The Creusot Works were the first to make use of nickel. The author publishes in tabular form the full results of a series of mechanical tests of various steels intended for armour-plates. These showed the following results as regards tensile strength and limit of elasticity:—

No.	Composition.					Limit of Elasticity.	Tensile Strength.	Elongation.
	C.	Si.	Mn.	Cr.	Ni.			
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Tons per Sq. In.	Tons per Sq. In.	Per Cent.
1.	0·45	0·20	0·50	0·0	0·0	25·5	44·3	17·0
2.	0·44	0·18	0·81	0·0	0·0	23·9	39·4	20·8
		...	...	...	...	19·0	35·5	23·0
	...		...	...	...	31·1	44·4	30·2
3.	0·45			1·80	0·00	28·6	39·2	19·5
4.	0·34	0·10	0·80	1·30	0·00	16·7	28·8	27·7
5.	0·46	0·16	0·48	1·52	0·00	30·9	43·7	16·0
6.	0·30	...	0·55	0·70	0·00	18·2	35·3	24·0
7.	0·24	0·05	0·48	0·19	1·70	38·4	47·6	13·2
8.	0·26	trace	0·25	0·65	2·00	.	41·6	19·3
9.	0·30	0·05	0·14	0·80	2·40	32·4	41·9	15·0
10	0·40	0·04	0·15	0·75	2·45	34·2	50·8	15·9
11	0·38		0·49	0·76	2·38	43·1	51·2	18·5
12	0·31		0·35	0·45	2·06	35·7	45·7	17·7
13	0·52	0·18	0·28	0·75	1·80	25·8	44·0	30·7
14	0·45	0·10	0·12	0·62	2·00	43·0	53·6	15·8
15.	0·33	0·14	0·30	0·50	2·54	41·1	51·9	15·0

Sample No. 1 was ordinary armour-plate; No. 2 (*b* and *c*) nickel steel, containing about 2·5 per cent. of nickel and no chromium. It will be observed that the steels submitted to mechanical test were in some cases annealed, and in others hardened at varying temperatures.

* *Annales des Mines*, vol. xiv. pp. 225–347.



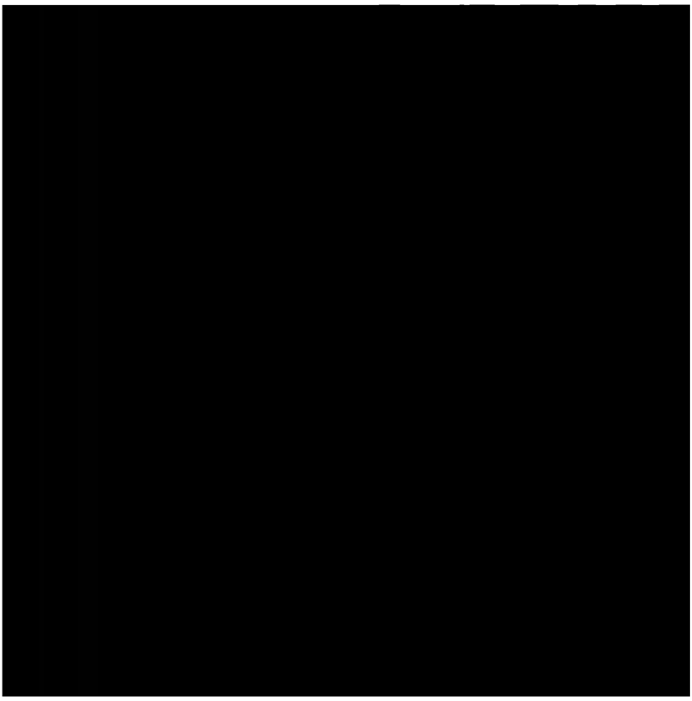
in the form of sound ingots, and their subsequent treatments presents considerable difficulties.

The authors determined the coefficient of expansion on heating of steels with gradually increasing percentages of nickel. Up to 20 per cent. of nickel they show very little difference from each other, but then they increase rapidly—by some 70 per cent.—until the steel with 25 per cent. of nickel is reached. From this point on there is a steady fall until the steel with 36 per cent. of nickel is reached, the elongation of which is extremely slight indeed. After that it again increases, as will be seen from the following :—

Percentage of Nickel.	Average Expansion between 0° C. and T° C., Expressed in Thousandths of Millimetres or Microns.
0·0	10·354 + 0·00523 T
5·0	10·529 + 0·00580 T
19·0	11·427 + 0·00362 T
24·0	17·484 + 0·00711 T
28·0	11·288 + 0·02889 T
34·6	1·373 + 0·00237 T
36·1	0·877 + 0·00127 T
36·4	1·058 + 0·00320 T
44·5	8·508 − 0·00251 T
100·0	12·661 + 0·00550 T

Intermediary results are also given. It will be observed that the expansion in the case of the steel with 36·1 per cent. of nickel was only about 0·8 to 0·9 micron; whilst that of platinum-iridium is some 8 microns. This steel is therefore very well adapted for standard measures and instruments of precision.

Steel with 20 to 25 per cent. of nickel and 2 to 3 of chromium is produced regularly at the Imphy Works, an open-hearth being employed. Besides possessing high mechanical properties, it is non-magnetic at ordinary temperatures, and offers a much greater degree of resistance to corrosion than does ordinary mild steel. The author mentions a number of uses to which this metal might, he considers, be advantageously put. A metal, too, with 12 to 12½ per cent. of nickel and 1 per cent. of chromium is also of a highly satisfactory character. In concluding, the author observes that while nickel and chrome steels appear to have an important future before them, this is not the case with high silicon steels, despite the remarkable properties which it is possible to make them show.



CHEMICAL PROPERTIES.

Electrolytic Iron.—F. Haber * has investigated the iron deposited electrolytically in the manufacture of plates for printing bank-notes. This iron is deposited very slowly, and gives an exceptionally hard printing surface. The material is found to contain 0·012 to 0·110 per cent. of hydrogen, thus confirming the investigations of Lenz. By using higher current densities, the percentage of hydrogen is increased.

The Carbides of Iron.—A recent publication of the Smithsonian Institution consists of a bibliography, prepared by J. A. Matthews, of the metallic carbides. The reference to the carbides of iron is short, for, as the author points out, although the literature of the subject is immense, a large proportion of it is devoted rather to physical than to chemical matters.

Aluminium as a Reducing Agent.—H. Goldschmidt † has utilised aluminium as a reducing agent, and as a means of producing very high temperatures. By mixing the metal in a fine state of division with some oxidising body, preferably peroxide of barium, and using magnesium to start the ignition, a heat is attained sufficient to fuse chromium. The process was first used for the preparation of chromium and manganese. The oxides of these metals with the mixture are placed in a crucible and ignited. Fresh additions of material are made as the fusion proceeds, and the process may be made continuous by tapping off the fused materials. The crucible used is made of magnesia, or lined with that substance. The metallic product is free from aluminium if a slight excess of oxide is provided, and the purity of the product is ensured by the purity of the raw material. Alloys of iron with 20 per cent. or more of titanium, and with 20 to 25 per cent.

* *Zeitschrift für Elektrochemie*, through *Engineering*, vol. lxv. p. 638.

† *Zeitschrift des Vereines Deutscher Ingenieure*, vol. xlii. pp. 1019–1022.

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Sample I. was from soft Saxon puddled iron containing 0·08 per cent. of manganese and 0·25 per cent. of phosphorus; II. and III. soft puddled iron from Upper Silesia; IV. Styrian puddled steel containing 1·42 per cent. of carbon, 0·12 of manganese, and 0·14 of silicon; V. mild basic steel from a Saxon works; VI. and VII. similar metal from works in Upper Silesia; VIII. Styrian crucible steel, containing 0·93 per cent. of carbon, 0·13 of manganese, and 0·31 of silicon.

Comparing the different analyses it will be seen that in every case the scale from soft basic steel contains more ferrous oxide and less ferric oxide than the scale from wrought iron. This is due to the fact that it is customary to work the latter at higher temperature. It is remarkable that the opposite holds good for steel. It will be seen that the scale from crucible steel is richer in ferric oxide than any other sample that was examined. The ratio of oxygen to iron appears to vary approximately between the limits Fe_3O_4 and Fe_4O_5, the average for the whole eight samples being $Fe_{[illegible]}O_{[illegible]}$. The total iron contents varies rather less, the average being 73·74 per cent.

Before analysis efforts were made to separate as completely as possible entangled iron particles, but in a few cases, on subsequently dissolving the samples, a faint evolution of hydrogen took place, showing that metallic iron was still present. In such cases somewhat too high results were consequently obtained in the case of the ferrous oxide. In samples V. and VI. metallic iron was probably present. With regard to the ratios in which the various impurities contained in the iron pass into the scale, it would seem that these were present in the scale in about the same proportions as they existed in the iron treated. The high percentages of silica found in samples IV. and VIII. are doubtless due to extraneous siliceous material that had attached itself to the iron from the furnace bottoms. These same two samples showed that the presence of a high percentage of carbon in the metal treated [illegible] difference in the composition of the scale formed. The [illegible] absence of sulphur is remarkable, and it must therefore be assumed that [illegible] was completely converted into sulphur [illegible].

Corrosion of Iron.—The results of some tests made at the Brooklyn Navy [illegible] steel and aluminium [illegible] water for [illegible] months have been published [illegible] compared

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carbon dioxide or phosphorus in the limestone in which the cable was anchored, but to the presence of water, which collected round the loops and could not escape. Where the cement in which the cable had been enclosed had been worn away, or rather where the cable had been allowed by faulty bedding to touch the masonry, the outer strands of the cable showed signs of rust in several places. The inner strands, however, showed no signs of rust.

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serve as a standard for analysis. The casting was made as a hollow cylinder in a sand mould with a sand core. The gate was made down to the bottom of the mould, so that the metal entered from the bottom, special care being taken in pouring not to introduce dirt or to wash away the sand. The pouring was continued until three or four hundred pounds of metal had run away from the riser, so that the metal in the body was kept well agitated. When solid, the casting was mounted in a lathe and the skin taken off, after which the turnings were collected, passed through a 40-mesh sieve, and thoroughly mixed. Samples prepared in this way, consisting of a pound of the turnings sufficient for thirty-six determinations, are to be supplied for use as a standard.

S. B. Marshall * gives the results of phosphorus and sulphur determinations made by twelve chemists using several different methods. The results may be tabulated as follows :—

Method.	Average.	Highest.	Lowest.
Sulphur—Aqua regia	0·052	0·058	0·0454
Evolution	0·049	0·053	0·044
Phosphorus—Magnesia	0·352	0·356	0·350
Volumetric	0·355	0·400	0·350
Yellow precipitate . . .	0·347	0·400	0·325

New Analytical Methods.—Adolphe Carnot † has published in collected form the various new methods of analysis described by him from time to time in the *Proceedings of the Academy of Sciences*. The papers are twenty-one in number, and include methods for the separation of iron and aluminium, and methods for analysing ores.

He also, in conjunction with Goutal,‡ publishes a paper on the use of copper salts in the analysis of iron and steel.

Sampling Pig Iron for Analysis.—A. L. Colby § discusses the methods of sampling pig iron for analysis. By means of numerous quotations from various authorities, it is shown that drillings from different pigs in the same cast, and even from different parts of the same pig, differ largely in composition. Two methods may be adopted. In the first, four small test ingots are cast by taking ladles-full near the beginning and end of the tap; equal portions of fine drillings from each of the ingots are mixed together and taken as the sample. A

* *Iron Trade Review*, vol. xxxi., No. 32, p. 10.
† *Annales des Mines*, vol. xiv. pp. 113–209. ‡ *Ibid.*, vol. xiv. pp. 210–223.
§ *Iron Age*, vol. lxi., June 2, pp. 13–16.

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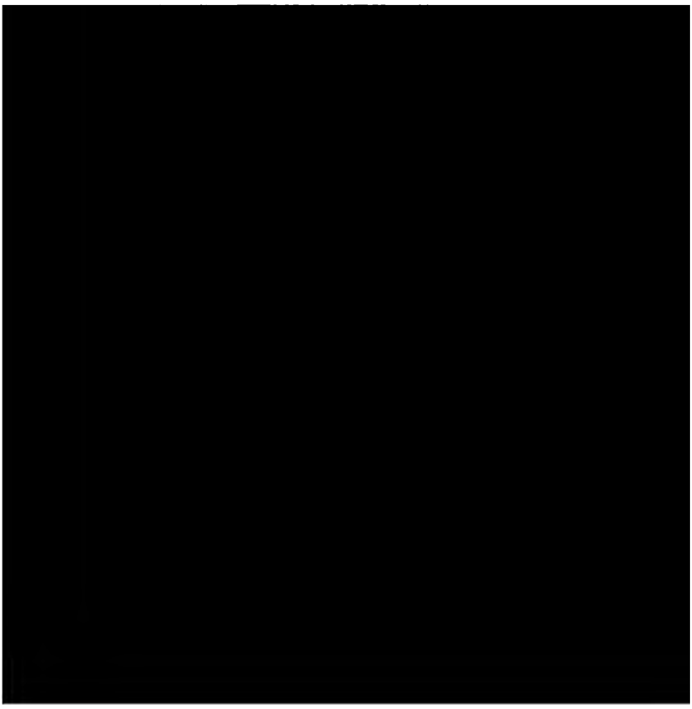


particulars:—First, the potash bulbs may not absorb all the carbon dioxide; second, the "prolong" containing calcium chloride may not absorb all the moisture drawn over from the potash bulb; third, the proportion of moisture so escaping from the prolong is not uniform and unvarying; fourth, the potash solution may lose something besides moisture; fifth, some chloro-chromic compound other than that absorbed by Professor Langley's "pyro" mixture may occasionally form and cause high results. A large number of experiments on these points are quoted.

G. Auchy * again deals with the error in carbon determinations made with the use of weighed potash bulbs due to the condensation of moisture on them. A number of experiments are given to show how the errors may be compensated.

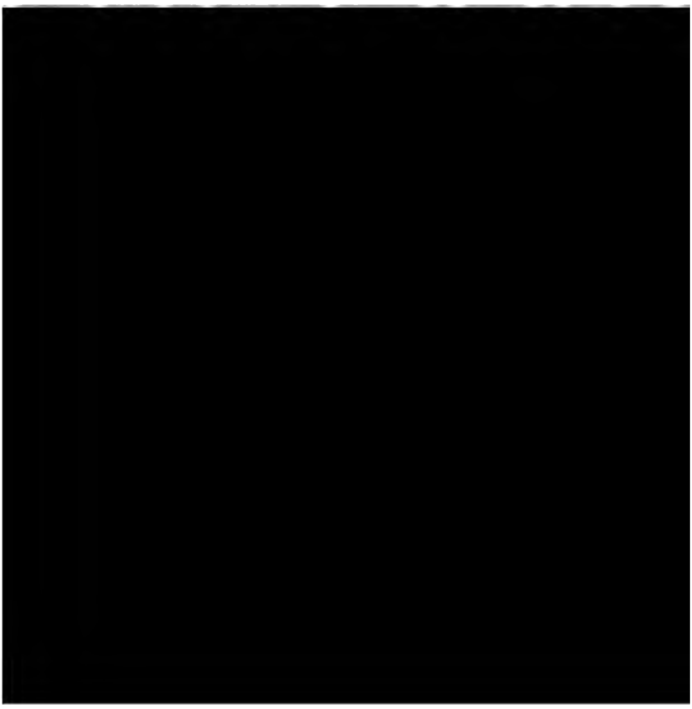
In the combustion method of carbon determination Rozycki † mixes the metal with a large excess of alumina and heats to redness in a current of oxygen, the volume of the carbonic acid formed being measured.

Determination of Phosphorus.—R. W. Mahon ‡ describes a method for the determination of phosphorus in low carbon and low silicon steel which is stated only to require some seven to eleven minutes for completion. To analyse drillings or filings, there is first placed in an Erlenmeyer flask of some 500 to 600 cubic centimetres capacity, 70 cubic centimetres of water, and 30 of nitric acid of 1·4 specific gravity. There is also prepared in a small beaker a definite quantity of a caustic soda solution. A burette is filled with the nitric acid, and the suction filter made ready for the reception of the molybdate precipitate. Four grammes of the filings are then charged into the flask containing the dilute nitric acid, and this is then immediately placed over the burner. When the metal is dissolved, 3 cubic centimetres of permanganate solution is added, and the whole boiled until decolorisation is complete. Ten cubic centimetres of hydrochloric acid of 1·2 specific gravity is then added, and the solution boiled until clear. It is then removed from the flame, and as soon as the boil has ceased, an addition is made of a mixture of 50 cubic centimetres of molybdate solution, and from 10 to 15 cubic centimetres of ammonia of 0·9 specific gravity. This mixture is prepared at the moment of use. This mixed solution is charged into the middle of the flask without allowing it to

* *Journal of the American Chemical Society*, vol. xx. pp. 528–534.

† *Revue Industrielle*, September 24, 1898.

‡ *Journal of the American Chemical Society*, vol. xx. pp. 429–438.



vapours; 200 cubic centimetres of water are then added, as also from 15 to 25 cubic centimetres of oxygenated water, and the whole titrated by means of permanganate. The analysis of pig iron varies according to the content of carbon. In the case of pig iron rich in graphite, 3 grammes of the sample are placed in 35 cubic centimetres of concentrated hydrochloric acid. This is evaporated almost to dryness; 50 cubic centimetres of concentrated nitric acid are then added, after which the contents are heated until all the red vapour disappears. The cooled solution is increased to a volume of 100 cubic centimetres, of which 50 cubic centimetres are evaporated to a syrupy consistency; 40 to 50 cubic centimetres of concentrated nitric acid are added, as also 1 to 2 grammes of chlorate of potash, the whole being boiled for from five to ten minutes. Water is then added, and the titration operation completed by means of oxygenised water and permanganate. In the case of pig iron containing little silicon or graphite, ½ gramme of the sample is dissolved in 15 cubic centimetres of hydrochloric acid; it is then heated and evaporated, afterwards boiled with 56 to 60 cubic centimetres of nitric acid; chlorate of potash is then added, and the operation concluded as above described. For manganese steel from 1½ to 5 grammes of the sample are dissolved in 25 cubic centimetres of hydrochloric acid; it is then heated and evaporated, afterwards boiled with 40 to 50 cubic centimetres of nitric acid, and the analysis is completed as above.

F. A. Gooch * and Martha Austin state that the estimation of manganese in its salts when combined with volatile acids, by weighing as the anhydrous sulphate, is found, contrary to previous investigations, to be both rapid and accurate. The solution is evaporated to dryness in the presence of sulphuric acid, and the excess of acid driven off by heating the residue in a platinum crucible suspended in a larger porcelain crucible used as a radiator. This outer crucible may be heated to dull redness, and the residue thus ignited to constant weight. The results show the process to be both simple and accurate. The estimation of manganese by weighing as the different oxides is described, but is found by experiment to be less satisfactory.

Determination of Silicon.—In determining silicon in steel, G. Auchy † recommends that the evaporation be performed with aqua regia and sulphuric acid instead of with nitric and sulphuric acids,

* *American Journal of Science*, vol. clv, pp. 209-214.

† *Journal of the American Chemical Society*, vol. xx. pp. 347-349.

and then into barium sulphate, (*b*) by iodometric titration, and (*c*) by the author's colorimetric process.

Maurice Lucas * describes an application of the colorimetric method for estimating lead to the estimation of sulphur in iron, steel, and cast iron. The metal is heated in a current of hydrogen with a mixture of dilute hydrochloric and sulphuric acids, the gases evolved being passed through a red-hot porcelain tube, and finally received in a solution of lead oxide in caustic potash. The precipitated lead sulphide is filtered off, washed with water, with dilute acetic acid, and then again with water, dissolved in nitric acid, the solution neutralised with caustic soda, suitably diluted, and examined colorimetrically according to the author's process for the estimation of lead.

Determination of Chromium.—According to E. L. Leffler,† Galbraith's method of estimating chromium in steel or iron is shown to give results varying with the proportion of acid used for solution, and also with the magnitude of the excess of permanganate employed. It is necessary to make a blank experiment under exactly the same conditions as those used in the analysis, and to subtract the value so obtained from the amount of chromium found.

Determination of Nickel.—J. Neumann ‡ observes that the ordinary methods for the determination of nickel are less simple and in part less accurate than most other determinations. It is only electrolysis that permits of the simple and rapid determination of the percentage of nickel in a solution. When iron is present with the nickel, the only possible solution for electrolysis is the ammoniacal one. If the quantity of iron present is not small, it is first precipitated by ammonia, filtered off, and the filtrate electrolysed direct after the addition of ammonium sulphate. When large quantities of iron are present, as is the case in nickel steel, the position is different. [illegible] and three or four [illegible] necessary before the iron precipitate is [illegible] is very bulky [illegible] become [illegible]. The [illegible] ammonium salts [illegible] the same [illegible] bulky solutions. [illegible]

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According to Perillon * a quantity varying from 0·25 to 4 grammes of the sample is dissolved in nitric acid of specific gravity 1·2, and, after the excess of acid has been expelled by boiling, enough aqueous potash is added to precipitate the metals; 25 grammes of oxalic acid is then added, and the whole dried at 80°. On boiling the dried mass with 100 cubic centimetres of a mixture of equal volumes of water, acetic acid, and alcohol for some time, and finally keeping [illegible] at 80°, the nickel oxalate is completely precipitated, and may be obtained free from alkalies by washing it with a 10 per cent. [illegible] of oxalic acid. On ignition it leaves nickel oxide, which may be freed from traces of iron and manganese by dissolving it in [illegible] acid and then adding bromine water and ammonia; the precipitate containing the iron and manganese is weighed, and the necessary [illegible] made.

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Determination of Sulphur in Blast-Furnace Slag.—[illegible]

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Analyses of Re[illegible]—[illegible]

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Ash.—Burn the portion of coal used for the determination of moisture, at first over a very low flame, with the crucible open and inclined, till free from carbon. If properly treated this sample can be burned much more quickly than the dense carbon left from the determination of volatile matter.

Fixed Carbon.—This is found by subtracting the percentage of ash from the percentage of coke.

The committee would recommend that the heating effect be calculated on the basis of the coal burned to carbon dioxide and vapour of water at 100° C., and be stated either in calories per kilogramme or English heat-units per pound. The theoretical evaporative effect is to be calculated by dividing the number of calories per kilogramme by 536, or the number of English heat-units per pound by 965. In either case it expresses the theoretical number of kilogrammes or pounds of water converted into steam from and at 100° C. by 1 kilogramme or pound of the coal.

Haber and Grimberg * use platinised asbestos in place of cuprous oxide in the combustion tube for making a combustion of coal.

Determination of Sulphur in Coal.—G. L. Heath † presents a short study of methods for the estimation of sulphur in coal, and is of the opinion that the methods of Eschka and Hundeshagen, which involve a simple ignition at low temperature, with a sulphur absorbent, are far preferable as rapid operations, for technical work, to any plan necessitating a complete fusion with a consequent solution of silica. The two preferred methods will uniformly furnish accurate results, within usual limits of error in sampling, if the operator will only exercise a little judgment in certain cases.

With anthracite coal and coke there is no liability to error. With softer fuels, especially lignites, the materials should be especially well ground, well mixed, and stirred during the ignition in an open dish, and if the proximate analysis and the appearance of the ash indicates that the coal contains a large percentage (over 3 per cent.) of sulphur as pyrites (or calcium sulphate in the ash), the boiling and washing should be continued for a longer time, and the washed residue finally dissolved in acid, and qualitatively tested by itself.

* *Industries and Iron*, vol. xxiv. p. 413.

† *Journal of the American Chemical Society*, vol. xx. pp. 630–637.

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STATISTICS.

CONTENTS.

I.—*UNITED KINGDOM.*

Mineral Statistics.—According to the official report of Her Majesty's Inspector of Mines,* the production of coal in the United Kingdom in 1897 amounted to 202,129,931 tons. The production during the previous year was 195,361,260 tons. The total quantity of iron ore raised in 1897 was 13,787,878 tons, of which 10,009,940 tons was obtained from mines and 3,777,938 tons from quarries.

The production of pig iron in 1897 is officially stated to have been 8,796,465 tons. The estimate of the British Iron Trade Association was 8,789,455 tons. There were 380 furnaces in blast.

The question of the coal production and consumption of the Pacific and the Far East has been considered in a recent article.† The present annual production is estimated at 23,000,000 tons, of which half is produced in British possessions, and the exports of the United Kingdom to the east of the Cape of Good Hope and west of Cape Horn at 1,700,000 tons.

* *Mines and Quarries. General Report and Statistics for 1897.* Part III. Output. London, 1898.

† *Statist*, vol. xli. pp. 875-876.

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[illegible] [illegible]

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[illegible] with [illegible] tons in the previous year. The total [illegible]

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II.—*AUSTRALASIA.*

Mineral Statistics of New South Wales.—The production of coal in New South Wales in 1897 is officially stated * to have been 4,383,591 tons. There were 92 collieries affording employment to 9979 persons. There were also produced 34,090 tons of Boghead mineral and 64,202 tons of coke. The amount of pig iron made was 3239 tons.

Mineral Statistics of New Zealand.—According to the Annual Statement of the Minister of Mines the production of coal in New Zealand in 1897 was 840,713 tons, and that of manganese ore 180 tons.

Mineral Statistics of Victoria.—According to the official returns † the quantity of coal raised in 1897 amounted to 236,277 tons.

Mineral Statistics of Tasmania.—According to a statement issued by the Mines Department the production of coal during the half year ending June 30, 1898, was 13,755 tons, and that of iron ore was 404 tons.

III.—*AUSTRIA-HUNGARY.*

Mineral Statistics.—The Austrian official mineral statistics for 1897 have been published. The principal items are as follows:—

	Metric Tons.
Coal	10,492,700
Brown coal	20,458,000
Iron ore	1,613,000
Pig iron	887,900

The output of iron and coal has rapidly increased of late years.

Further details are published ‡ as to the mineral industry of Austria in the year 1896. In Bohemia a good deal of exploratory work was done and a number of seams of coal were discovered, and in other

* *Annual Report of the Department of Mines*, Sydney, 1898, p. 25.

† *Annual Report of the Secretary for Mines*, Melbourne, 1898, p. 16.

‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvi. pp. 325–327, 358–360, 378–380, 392–395, 428–429, 439–441, 455–456, 474–475, and 488–489.

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Austria, where a fire led to sixteen miners losing their lives, and eighteen being severely injured.

The undertakings that existed in Austria in 1896 for the getting of petroleum numbered 332, of which 221 were active. The production of petroleum amounted to 262,356 tons, an increase of 39·08 per cent. The workpeople employed numbered 4522, more than half being in the Jaslo mining district. The price of the oil diminished somewhat during the year, but the total value increased by 16·23 per cent. At Schodnica, in the Drohobycz district, 144,908 tons of oil was produced during the year, this being apparently either the largest, or at least one of the largest, producing places. Most of the total output went to Galicia for further treatment. The workings included 592 shafts, 50 only of which were getting oil; and also 1974 boreholes, 1185 of which were producing.

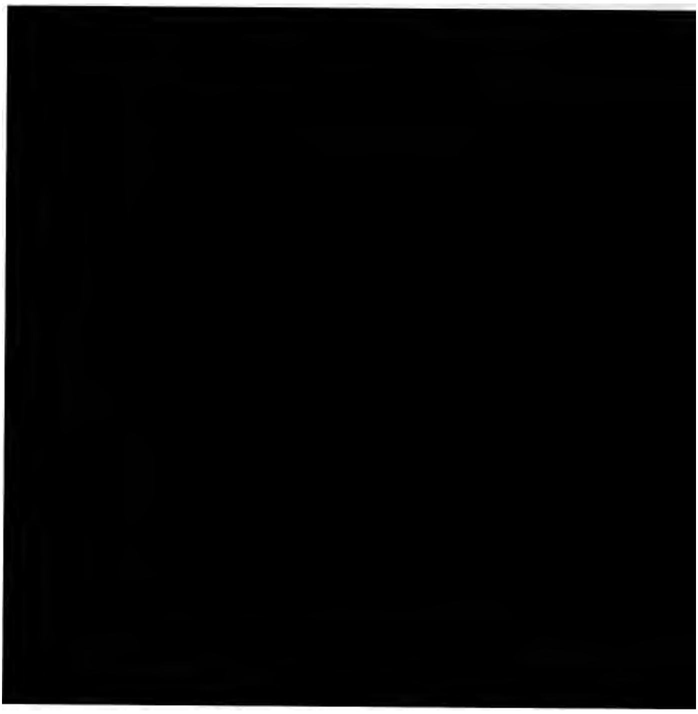
The number of ozokerite workings was 70, 52 of which were in active operation, and the remainder idle. The production amounted to 6573 tons, a diminution of 192 tons on the year. The workpeople employed numbered 5689. The value of the product was 1,776,853 Austrian florins, say £150,000.

The accidents at the petroleum and ozokerite workings during 1896 amounted to 52, 15 of which were fatal.

The number of fire-damp explosions that occurred in Austria in 1896 was 17. These led to the deaths of 2 miners, while 21 were severely and 7 slightly injured. Five of these explosions were at collieries, 6 at brown-coal mines, and 6 at oil workings. Thirteen of these explosions occurred at depths not exceeding 200 metres (656 feet). The immediate causes of these explosions was stated to have been in five cases the sudden outburst of gas, and in four faulty ventilation. The gases caught fire in nine cases owing to the use of open lights, and in two cases to petroleum dropping on the wire gauze of the safety-lamps.

The Iron Industry of Austria.—W. Hupfeld * considers the present position of the iron industry of Austria. The last three years have shown considerable progress, the increase of production being a general one, and not confined to a few branches of the industry, and this is shown by statistics. Incidentally reference is made to the production in other countries, and to the home consumption. He compares

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvi. pp. 383-386, and 402-406.



Exports.

	1896.	1897.
	Metric Tons.	Metric Tons.
Brown coal	7,562,721	8,108,975
Coal	658,368	701,919
Coke	116,698	145,056
Manganese ore	701	622
Iron ore	214,390	247,856
Iron and iron wares	41,813	50,284

Full details are given under a considerable number of headings as to the various items.

The imports included the following:—

Imports.

	1896.	1897.
	Metric Tons.	Metric Tons.
Brown coal	19,981	19,609
Coal	5,174,321	5,121,475
Coke	491,028	533,463
Manganese ore	7,371	8,018
Iron ore	107,018	137,478
Iron and iron wares	197,936	212,187

It will be seen, the author observes, that the annual increase in the exports of brown coal still continues, and that in 1897 it was as much as about 7 per cent. in excess of the exports in the previous year. Nearly the whole of it—99·6 per cent.—is sent to Germany. In coal and coke there has been an increase in the exports. In the case of the latter the increased exports have been to Russia. The imports of iron and iron wares have increased by 14,151 tons, or 7 per cent., and the exports by 8470 tons, or 20 per cent. Of the imports 76 per cent. consisted of pig iron and scrap, and of the exports 20 per cent. Of the imports 55 per cent. was from the United Kingdom, 94 per cent. of this quantity consisting of pig iron, ferro-manganese, and scrap. Of the remaining 45 per cent. of the total imports of iron and iron wares, 29 per cent. was from Germany. Fifty-five per cent. of the German imports were manufactures, only 45 per cent. being pig iron and scrap. The exports were as follows: To Italy 21 per cent., to Germany 18 per cent., to Roumania 15 per cent., to Russia and Servia each 12

IV.—BELGIUM.

Mineral Statistics.—The annual report of E. Harzé* contains details of the production of every colliery in Belgium. In 1897 there were 117 collieries in the kingdom, the total production amounting to 21,492,446 tons. The imports were 2,017,000 tons, and the exports 4,449,000 tons. The most productive colliery was Bascoup, with an output of 889,710 tons. The iron trade production comprised 240,774 tons of iron ores, 1,035,057 tons of pig iron, 474,819 tons of wrought iron, and 616,541 tons of steel ingots.

The iron trade statistics of Belgium for the first half of the present year show that the production of pig iron amounted to 490,503 tons, that of wrought iron to 265,807 tons, and that of steel ingots to 307,[illegible] tons.

[illegible]

Mineral Statistics.—According [illegible] E. D. Ingall,† [illegible] 1897 [illegible]—

	Tons.
[illegible]	7,[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]

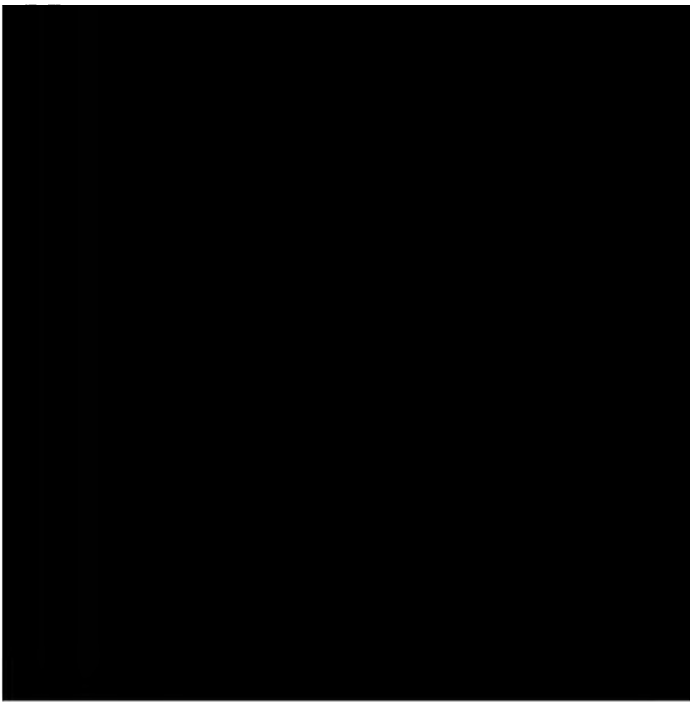
[illegible]

[illegible]

	Tons.
[illegible]	24,[illegible]
[illegible]	[illegible]

[illegible]

[illegible]



The production of basic and acid open-hearth steel ingots in 1897 was 18,400 tons, against 16,000 tons in 1896, and 17,000 tons in 1895. Of the total production of open-hearth steel in 1897 a little less than three-fifths was made by the acid process. The production of open-hearth steel rails in 1897 amounted to 500 tons, against 600 tons in 1896; structural shapes 4300 tons, against 4540 tons in 1896; cut-nails made by rolling-mills and steelworks having cut-nail factories connected with their plants, 202,939 kegs of 100 lbs., against 196,971 kegs in 1896; plates and sheets, about 2000 tons, against 1820 tons in 1896; all other rolled products, excluding muck and scrap bar, blooms, billets, sheet bars, &c., 61,161 tons, against 59,290 tons in 1896. Changing the cut-nail production from kegs of 100 lbs. to tons of 2240 lbs., the total quantity of all kinds of iron and steel rolled into finished products in the Dominion in 1897, excluding muck and scrap bar, billets, &c., amounted to 77,021 tons, against 75,043 tons in 1896, and 66,402 tons in 1895.

The total number of rolling-mills and steelworks in Canada on December 31, 1897, was seventeen. Of this number at least three were idle during the whole of 1897.

VI.—FRANCE.

Iron Trade Statistics.—The *Comité des Forges** has just published the French iron trade statistics for the first half of 189[illegible]. The production was as follows:—

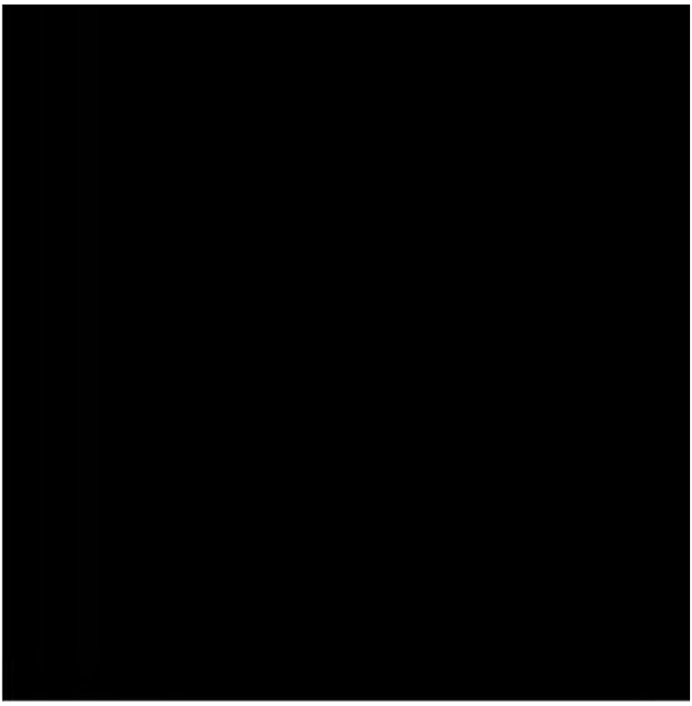
	Metric Tons.
Pig iron	1,[illegible]
Wrought iron	40[illegible]
Steel	70[illegible]

The imports and exports during the same period were as follows:—

	Imports.	Exports.
	Tons.	Tons.
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]

[illegible] during the same period was [illegible] 244,01[illegible] tons.

* [illegible] No. 135.



Exports.

	First Half of 1898. Metric Tons.
Iron ores	1,476,015
Iron slags	13,380
Basic slags, ground	52,412
Pig iron	91,365
Scrap iron	47,373
Ingots, blooms, &c.	20,021
Manufactures	496,530
Semi-manufactures	157,077
Total of all kinds	937,736
Total value, £ sterling	£13,898,800

The total imports of iron of all kinds into Germany during the years 1886–97 has risen from 266,738 to 691,584 tons; the exports have advanced from 1,594,946 to 2,036,463 tons; and the total home consumption has increased from 2,200,450 to 5,534,662 tons. The calculated consumption per head has increased in the eleven years from 104 to 230 lbs., and the production per head has increased from 166 to 285 lbs. The consumption per head has considerably more than doubled, while the production has increased by over 70 per cent.

Mineral Statistics of Prussia.—According to the official statistics,* the mineral production of Prussia last year included—

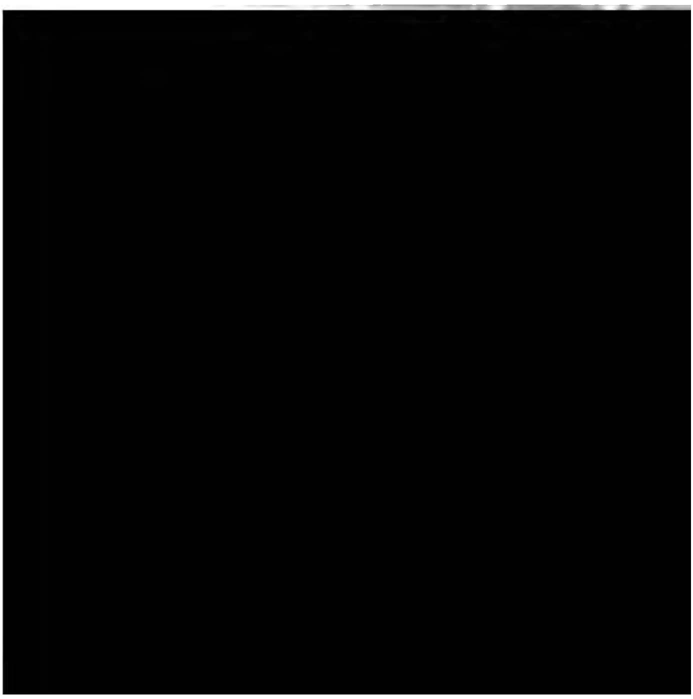
	Tons.
Coal	84,253,393
Brown coal	24,222,911
Asphalt	11,466
Petroleum	2,600
Iron ore	4,183,536
Manganese ore	45,253

Mineral Statistics of Upper Silesia.—The mineral statistics of Upper Silesia for last year have been issued by H. Voltz † and by Dr. Leo.‡ There were fifty-five collieries in operation with 1002 steam-engines, and an output of 20,636,653 tons of coal, or 356·8 tons per miner employed. The forty-four iron ore mines produced 414,671 tons, and afforded employment to 3195 workpeople.

* *Zeitschrift für das Berg- Hütten- und Salinenwesen im preussischen Staate*, vol. xlvi. pp. 2–28.

† *Stahl und Eisen*, vol. xviii. pp. 574–575.

‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvi. pp. 418–421



purposes 614,606 tons of coal, and 3369 tons of coke and cinder were also used. The following quantities of ingots were produced—

	Metric Tons.
Acid Bessemer	33,818
Basic Bessemer	150,529
Basic open-hearth	222,009
Acid open-hearth	2,089

And these with other semi-manufactures produced brought the total production of semi-manufactures to 515,705 metric tons.

A large number of details are also given relating to the other products of the iron and steel works and rolling-mill plants, and other metals are also dealt with.

Mineral Statistics of Bavaria.—According to the official statistics,* the mineral production of Bavaria in 1898 comprised—

	Mines.	Output in Tons.	Workmen Employed.
Coal	17	917,021	5792
Lignite	7	39,043	210
Iron ore	41	172,699	698
Manganese ore	2	130	3

The metallurgical production included—

	Metric Tons.
Pig iron	83,418
Direct castings	138
Cast iron	78,008
Wrought iron	58,200
Iron wire	252
Steel	115,529

Mineral Statistics of Thuringia.—The returns of the Imperial Statistical Bureau at Berlin show that the condition of the mineral industry of the Thuringian States in 1896 was as follows: Coal was produced from 2 mines with 125 miners in the Duchy of Meiningen, and from 1 mine with 8 miners in the Duchy of Saxe-Coburg Gotha. Brown coal was raised from 39 mines with 1858 miners in Saxe-Coburg Gotha, from 1 mine with 72 miners in the principality of Schwarzburg-Rudolstadt, from 1 mine with 53 miners in the princi-

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvi. pp. 486–487.

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established in the case of such foreigners as cannot show certificates of general education comparable to those required from German students.*

VIII.—*INDIA.*

Production of Coal.—There were 145 coal mines in operation in British India in 1897, of which 128 were located in Bengal.† The output from the Bengal mines was reported to amount to 3,142,497 tons; 131,629 tons were raised from the Central Provinces collieries (Mohpani and Warora); 185,533 tons from the Assam collieries; 124,778 tons from Umaria (Central India); 92,792 tons from the Dandot and Bhaganwala collieries in the Punjab; 365,550 tons from the Singareni colliery in the Nizam's territory; 8876 tons from the Khost and Sharigh mines in Baluchistan; 11,472 tons in the Shwebo district in Burma. The annual output and the number of workpeople employed in all India has been as follows:—

	Tons.	Workers.
1893	2,562,001	37,679
1894	2,830,652	43,197
1895	3,537,820	57,919
1896	3,848,013	61,958
1897	4,063,127	59,859

The imports of coal, coke, and patent fuel in 1897–98 amounted to 262,844 tons, valued at Rx. 538,284. In the preceding year the imports were 494,960 tons, valued at Rx. 979,022.

Indian coal exported by sea from Bengal has been as follows:—

Years	To Bombay and Sind.	To Madras.	To Burma.	To Ceylon and other Countries.
	Tons.	Tons.	Tons.	Tons.
1893–94	85,439	57,996	96,884	52,302
1894–95	51,971	54,923	77,041	53,665
1895–96	161,791	32,942	147,729	80,923
1896–97	290,038	146,342	96,710	136,719
1897–98	543,461	203,232	169,788	212,855

* *Stahl und Eisen*, vol. xviii. p. 422.

† *Board of Trade Journal*, vol. xxv. pp. 49–50.

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	1886.	1896.
	Tons.	Tons.
Navigation	247,130	740,753
Railways	18,306	221,321
Factories	146,570	1,188,563
Salt works	455,794	517,415
Total	867,800	2,668,052

In 1895 there were 1570 collieries in the whole of Japan, 54,690 miners being employed. The chief shipping ports for coal are on the island of Kiusiu, the exports from these being last year as follows:—

Port.	Quantity.	Value.
	Tons.	$
Nagasaka	392,849	2,111,993
Modji	672,155	3,771,690
Karatsu	72,958	307,007
Kutschinotsu	346,968	1,650,974
Hakada	42	252
Total	1,484,972	7,841,916

The total production of coal in Japan in 1896 is reported at 5,249,919 tons, which compares with 4,772,654 tons in 1895 and 4,268,135 tons in 1894. The exports were 2,194,412 tons in 1896, against 1,844,815 tons in 1895 and 1,701,130 tons in 1894.*

XI.—*RUSSIA.*

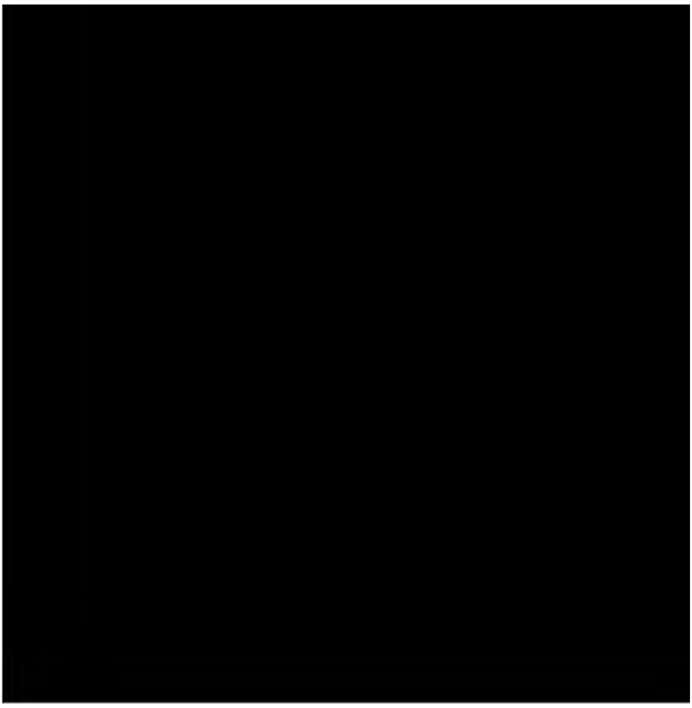
The Production of Iron and Steel.—The total production of iron and steel in the Russian Empire during 1897 † was as follows—

	Poods.
Pig iron	113,982,394
Manufactured iron	30,610,984
Steel	52,963,928

Thus the production of pig iron in 1897 exceeded that of the previous year by 15,197,000 poods.

The importation of foreign iron and steel in 1897 was as follows: pig iron, 6,238,000 poods; manufactured iron and steel, 24,294,000 poods; iron and steel articles, 1,834,000 poods; machinery, 4,545,000

* *Engineering and Mining Journal*, vol. lxiv. p. 693.
† *Gorny Journal*, May 1898.



The imports of pig iron, iron, and steel in 1897 exceeded those of the previous year by 2 per cent. During the last three years they have been as follows :—

	1895.	1896.	1897.
	Metric Tons.	Metric Tons.	Metric Tons.
Pig iron and castings	133,000	75,000	102,000
Unworked wrought iron and steel .	301,000	377,000	398,000
Machinery and apparatus . . .	98,000	86,000	75,000
Other iron and steel manufactures .	33,000	45,000	30,000

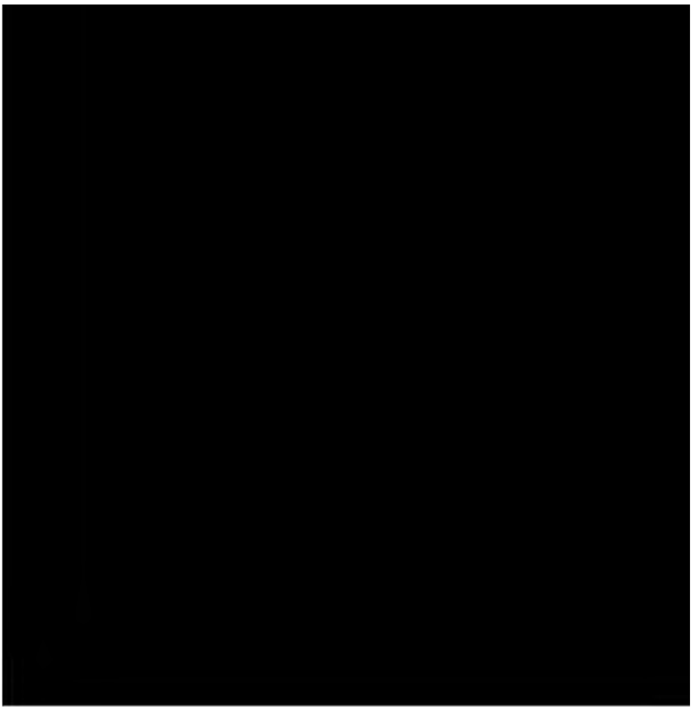
The total production of pig iron in Russia, and the total internal requirements, have been as follows during the past five years :—

Year.	Production.	Consumption.
	Metric Tons.	Metric Tons.
1893	1,162,000	1,679,000
1894	1,313,000	2,093,000
1895	1,446,000	2,234,000
1896	1,613,000	2,415,000
1897	1,870,000	2,727,000

It will be seen that the Russian Empire consumed over a million tons, or 62·7 per cent., more pig iron in 1897 than it did in 1893, and that the total home production had increased during this period by 705,000 tons, or 61 per cent.

The Iron Industry of Russia.—S. Kusnetzow * remarks that the iron industry of Russia is making very rapid progress. Ten years ago it occupied the tenth place in the world's production by countries, but now it has exceeded the production of Austria-Hungary and Belgium, and occupies the fifth place. In 1897, Russia produced 1,860,000 tons of pig iron, as compared with 1,615,000 tons in the previous year. This represents an increase of upwards of 15 per cent. on the year. With the increase in production of pig iron the quantity imported has diminished. On the other hand, the imports of iron and steel have continued to increase, as the following statistics show :—

* *Industrie- und Handelszeitung*, 1898, No. 43; *Stahl und Eisen*, vol. xviii. pp. 543-547.



tons of malleable iron. The manufacture of wrought iron in hearths is steadily diminishing, and in the last two years to the extent of 9·5 per cent. The exports to Russia were greater than for any other year since 1890.

Coal.—M. Aumard discusses * the mining industry of the south of Russia. The 422,503 waggons of coal despatched from the collieries of the district last year had the following destinations :—

To	Waggons.	Per Cent. of Total.
Railways	124,739	30·28
Gas works	4,980	0·64
Steamships	23,693	6·09
Smelting works	115,762	27·70
Sugar works	30,221	7·41
Various	123,108	27·88

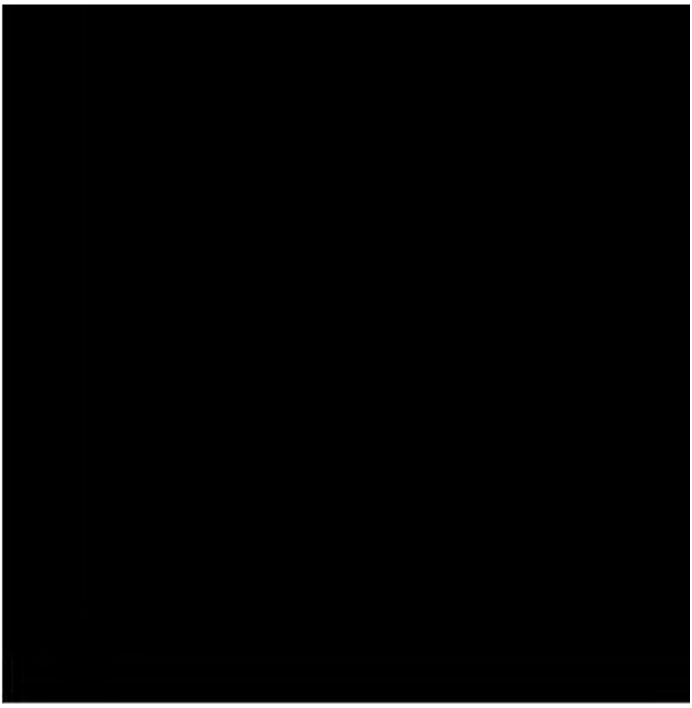
During the year the six principal iron works of the district despatched 61,912 waggons of iron and steel (each holding 600 poods).

The Adoption of Russian Fuel by the Baltic Fleet.—According to Professor Alexeeff,† the Ministry of Marine has long desired to replace English coal in the Russian fleet by Russian coal, and in November 1896 despatched their representative to the meeting of South Russian coal-owners, then sitting at Kharkoff, to inquire into the possibility of their supplying a sufficient quantity of first-class coal for this purpose. They answered in the affirmative, and stated their readiness to supply the fleet with coal containing—sulphur, 0·75 to 3·5 per cent. ; ash, 6 to 15 per cent. ; coke, 50 to 80 per cent. ; volatile matter, 15 to 38 per cent. The proportion of large coal to be as follows :—

	Per Cent.
For long flaming coal	60
For caking coal	30
For smithy coking coal	20

The amount of moisture was not fixed. As Professor Alexeeff remarks, such a coal would be far inferior to English coal. More recently a series of experiments have been made at the Tgora Works, near Petersburg, upon the comparative heating capacity of Newcastle and Donetz coal, and gave the remarkable result that the steam-giving capacity

* *Société des Ingénieurs Civils*, vol. li. pp. 350–354.
† *Gorny Journal*, May 1898.



Coalfield.	Number of Collieries.	Output.
		Tons.
Bokesburg	13	1,152,622
Heidelberg	8	272,348
Middelburg	18	176,176
Lijdenburg	1	31,657
Other fields	2	34,949
Total . . .	42	1,667,752

XIII.—*SPAIN.*

Mineral Statistics.—The Minister of the Interior has published the Spanish mineral statistics for 1897. The production of coal is stated to have been as follows:—

	Metric Tons.
Bituminous coal	2,010,960
Lignite	54,232
Anthracite	8,758
Total	2,073,950

The total for the previous year was 1,923,255 tons.

Iron Ore Exports.—Official returns have been issued showing the exports of iron ore from Spain in 1897. The quantities shipped at the different ports were as follows:—

Province.	Port.	Metric Tons.
Almeria	Almeria	159,187
"	Garrucha	360,124
Biscay	Bilbao	4,697,995
"	Povena	36,937
Guipuzcoa	Irun	6,507
"	Pasages	499
Huelva	Huelva	25,337
Malaga	Malaga	6,568
"	Marbella	42,546
Murcia	Carthagena	365,245
	Aguilas	62,739
	Mazarron	30,040
Oviedo	Gijon	237
Pontevedra	Vigo	50
Santander	Santander	349,477
"	Castro Urdiales	400,300
Seville	Seville	127,696

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of furnaces in blast was 183. Complete statistics for 1897 have also been published.*

The following is a summary of the principal statistics of production contained in James M. Swank's report for 1897 :—

	Tons.
Pig iron	9,652,680
Steel	7,156,957
Structural shapes	583,790
Plates and sheets	1,307,286
All rolled iron and steel except rails	5,353,836
Wire rods	970,736

The shipments of iron ore from Lake Superior amounted to 12,468,795 tons.

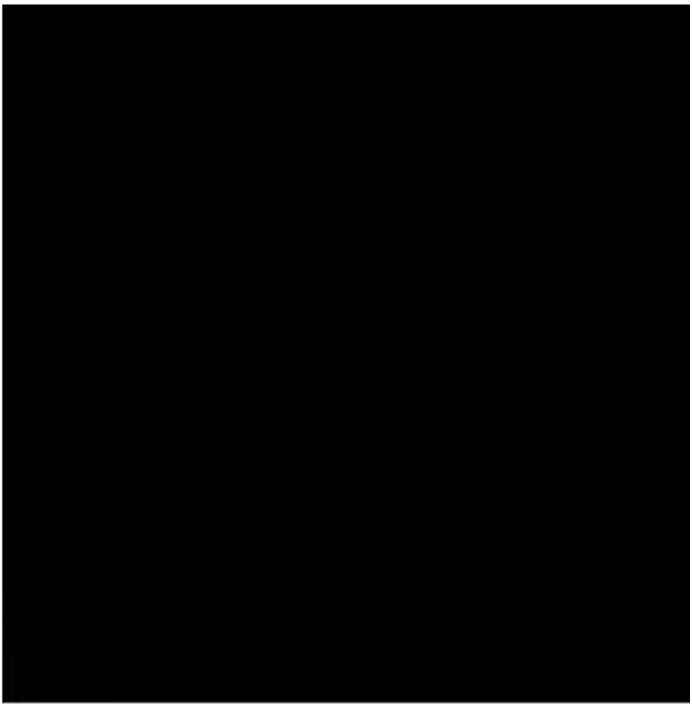
The iron and steel wire rod production of 1897 was the largest in the history of that industry in the United States. The total of 970,736 tons, against 623,986 tons in 1896 and 791,130 tons in 1895, showing an increase of 346,750 tons, or over 55 per cent., over 1896, and 179,606 tons over 1895.

In the table below the steel made in 1897 is shown. The statement does not include the make of crucible and special process steels, which amounts, however, to less than 1 per cent. of the total.

	1897.	
	Tons.	Per Cent.
[illegible] open-hearth	[illegible]	[illegible]
Basic open-hearth	[illegible]	[illegible]
Total open-hearth	[illegible]	[illegible]
Bessemer	[illegible]	[illegible]
Total	[illegible]	[illegible]

The total increase in the production in 1897, as compared with 1896, was [illegible] tons, or [illegible] per cent., a [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] per cent. The increase was [illegible] Bessemer steel showing an increase of [illegible] tons [illegible] open-hearth steel was [illegible] tons [illegible] per cent. [illegible] [illegible] open-hearth steel was [illegible] [illegible] tons of [illegible] per cent. [illegible]

* [illegible]



	Under 45 lbs.	45 lbs. and less than 85 lbs.	85 lbs. and over.	Total.
	Tons.	Tons.	Tons.	Tons.
Pennsylvania	51,574	711,827	264,675	1,028,076
Ohio and Illinois . . .	4,589	446,622	61,920	513,131
Other States	32,733	64,986	8,966	106,685
Total	88,896	1,223,435	335,561	1,647,892

The rails which are known to have been rolled for street and electric railways in 1897 amounted to 122,244 tons, against 145,210 tons in 1896, a decrease of 22,966 tons.

Poor's "Manual of Railroads" of the United States extends this year to 1492 pages. It shows that in 1897 the United States railways were 179,692 miles in length. There were 35,810 locomotives. There were 504,106,525 passengers carried, and 788,385,448 tons of freight moved.

Iron Ore.—John Birkinbine states that the production of iron ore in the United States last year was greater than ever before, exceeding as it did 17,500,000 tons. The proportion taken by each class of ore was as follows:—

	Tons.
Red hæmatite	14,400,000
Brown hæmatite	2,000,000
Magnetite	1,000,000
Spathic ore	100,000

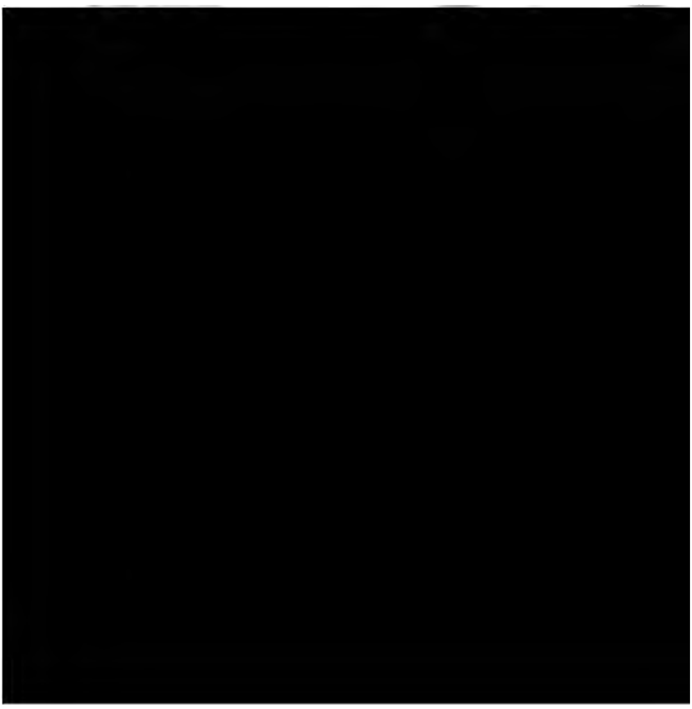
Coal.—The total production of coal in the United States in 1897,* as finally ascertained for the United States Geological Survey, amounted to 178,769,344 tons, of which 46,814,074 tons were anthracite, and 131,955,270 tons were bituminous.

Coke.—According to E. W. Parker,† the production of coke in the United States for the last three years has been as follows, the number of ovens being also given:—

	1897.	1896.	1895.
Production in short tons	13,288,984	[illegible]	13,333,714
Number of works	[illegible]	341	.
Number of ovens	[illegible]	46,944	.

* *Colliery Guardian*, vol. lxxv. p. 842.

† *Report of the United States Geological Survey*, through the *Iron Age*, vol. lxii. No. 2, p. 8.



A similar summary showing the production of pig iron is as follows:—

Country.	Year.	Production in Tons.
United Kingdom	1897	8,796,465
Austria	1897	887,900
Hungary	1896	400,815
Belgium	1897	1,035,037
Canada	1897	53,796
France	1897	2,472,143
Germany	1897	6,881,466
Italy	1897	8,393
Japan	1894	15,760
Russia	1897	1,857,000
Spain	1897	297,100
Sweden	1897	538,197
United States	1897	9,652,680

Coal. F. Kupelweiser* publishes an economic study of the world's coal supplies. He gives statistics for the different countries, extending over a large number of years. He shows that Europe, which in 1870 supplied 84 per cent. of the coal used, in 1897 supplied only 69 per cent. For the various countries the percentage share in the world's production was as follows in 1870 and in 1895:—

	1870.	1895.
Great Britain	[illegible]	[illegible]
Germany	[illegible]	[illegible]
Austria-Hungary	[illegible]	[illegible]
France	[illegible]	[illegible]
Belgium	[illegible]	[illegible]
Russia	[illegible]	[illegible]
North America	[illegible]	[illegible]
Other countries	[illegible]	[illegible]
Total	[illegible]	[illegible]

Imports and Exports of Iron Ore and Pig Iron.—The following comparative statement of the imports and exports of iron ore in [illegible] has been compiled from official sources:—

* [illegible]

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[redacted]

Cost of Labour.—A. L. Bowley * compares the changes in wages in France, the United States, and the United Kingdom, from 1840 to 1891. *Inter alia*, it is found that average nominal or money wages in 1840, expressed as percentages of those in 1891, were—mining, 61; iron, 77. The following table gives, for the three countries, the average nominal wages of all workers, as percentages of those in 1891 :—

Year.	United Kingdom.	France.	United States.
1840	61	52	49
1850	61	52	54
1860	73	65	59
1870	83	75	81
1880	89	86	85
1891	100	100	100

The conclusion might be stated roughly as follows: Reckoning from 1891, real wages had doubled in all these countries in less than fifty years, and increased by one-half in less than twenty years.

* Paper read before the British Association, September 1898.

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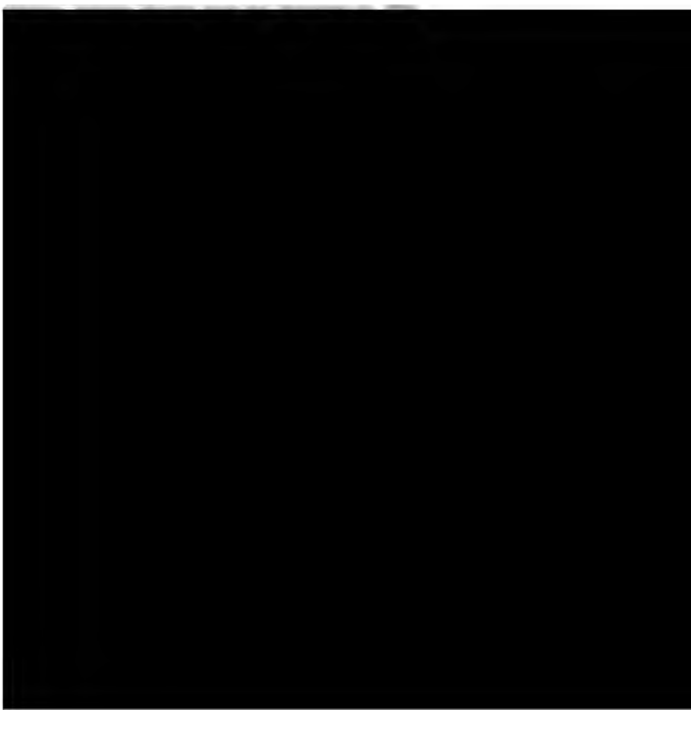

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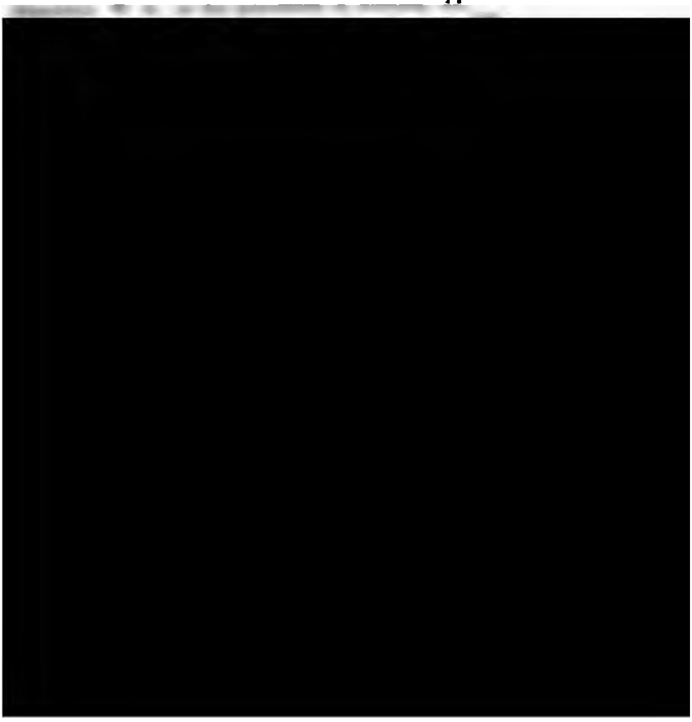

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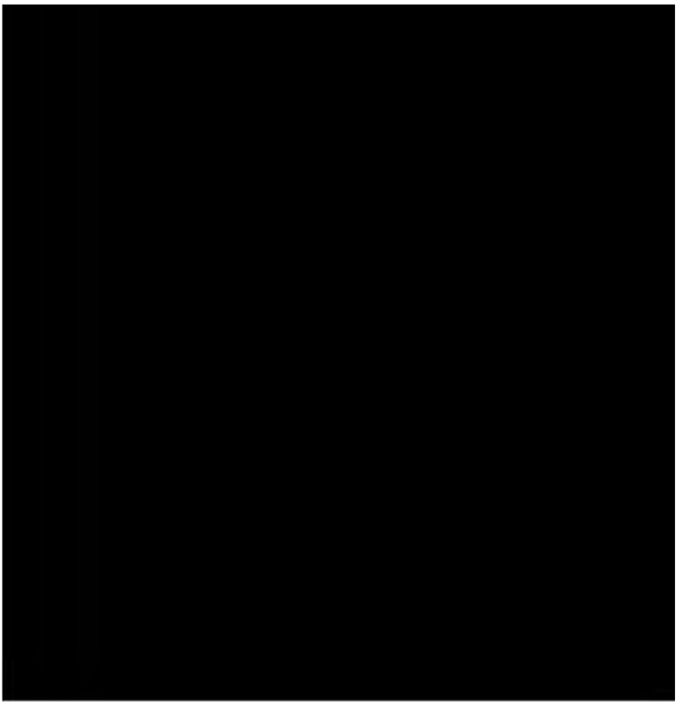

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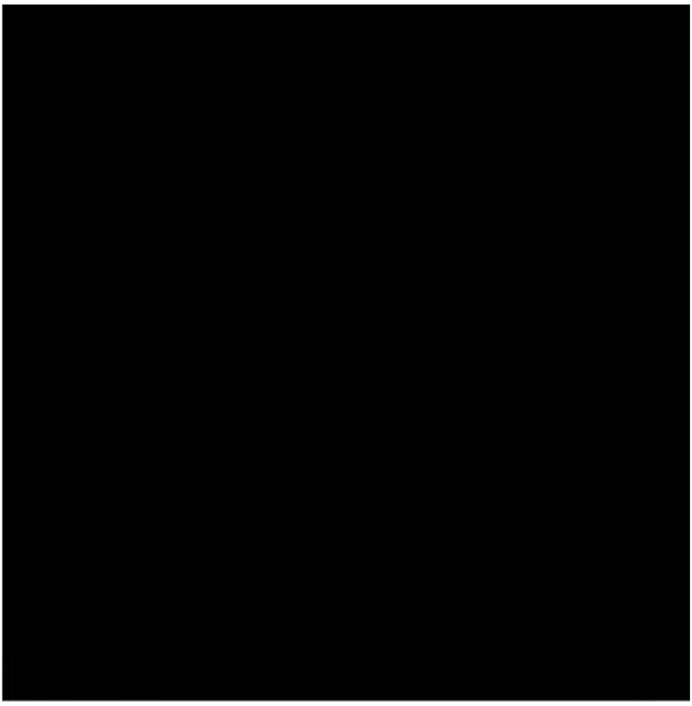

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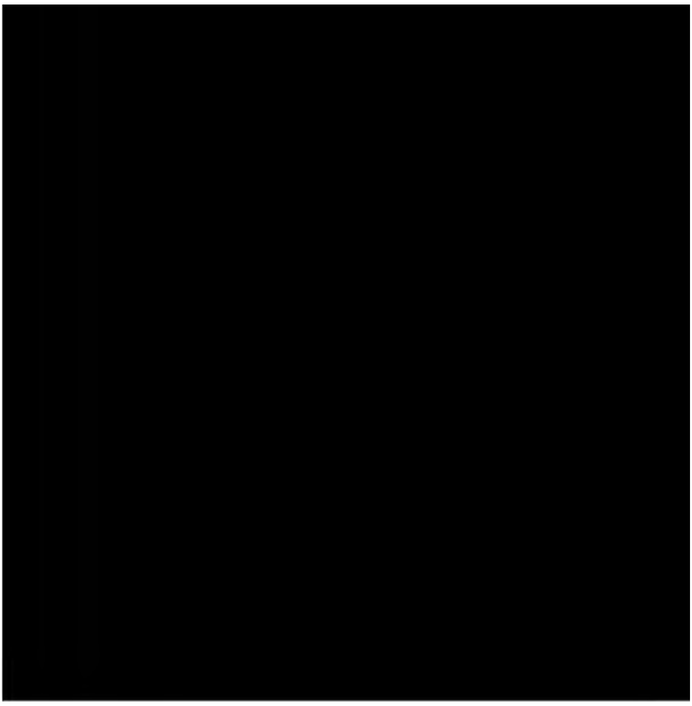

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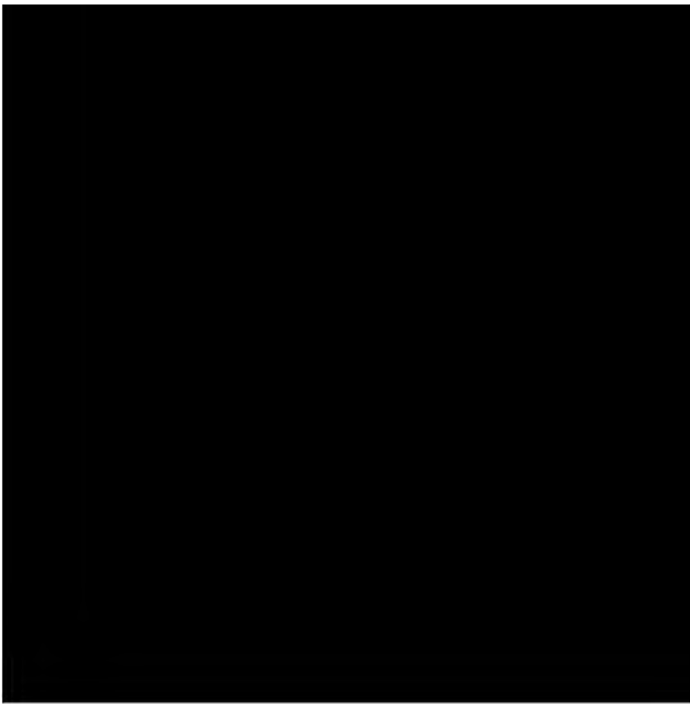

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